Lake Lucy and Lake Ann Use Attainability Analysis

Prepared for
Riley-Purgatory-Bluff Creek Watershed District

July 1999

BARR

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Executive Summary

Overview

This report describes the results of the use attainability analysis for Lake Lucy and Lake Ann. The use attainability analysis provides the scientific foundation for a lake-specific best management plan that will maintain or attain the existing and potential beneficial uses of Lake Lucy and Lake Ann. This study includes both a water quality analysis and potential protective measures for both lakes and their watersheds. The conclusions and recommendations are based on historical water quality data, the results of intensive lake water quality monitoring in 1997, and computer simulations of land use impacts on water quality in Lake Lucy and Lake Ann using watershed and lake models calibrated to the 1997 data set. In addition, best management practices (BMPs) were evaluated to compare the relative effect of BMPs on total phosphorus concentrations and Secchi disc transparency (i.e., water clarity).

Riley-Purgatory-Bluff Creek Watershed District Goals

The approved *Riley-Purgatory-Bluff Creek Watershed District Water Management Plan,* (Barr Engineering 1996b) (Plan) inventoried and assessed Lake Lucy and Lake Ann. The Plan articulated five specific goals for Lake Lucy and Lake Ann. These goals address:

- Water Quality
- Recreation
- Aquatic Communities
- Water Quantity
- Wildlife

Wherever possible, Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) goals for Lake Lucy and Lake Ann have been quantified using a standardized lake rating system termed the Carlson's Trophic State Index (TSI) (Carlson, 1977). This rating system considers the lake's total phosphorus, chlorophyll *a*, and Secchi disc transparency measurements to assign it a water quality index number that reflects its general level of fertility. The resulting index values generally range between 0 and 100, with increasing values indicating more fertile conditions.

Total phosphorus, chlorophyll *a*, and Secchi disc transparency are key water quality parameters upon which TSI statistics are computed, for the following reasons:

- Phosphorus generally controls the growth of algae in lake systems. Of all the substances needed for biological growth, phosphorus is typically the limiting nutrient.

- Chlorophyll *a* is the main pigment in algae. Therefore, the amount of chlorophyll *a* in the water indicates the abundance of algae present in the lake.

- Secchi disc transparency is a measure of water clarity and is inversely related to the abundance of algae.

Although any one or all three parameters can be used to compute a TSI, water transparency is most often used, since peoples' perceptions of water clarity are most directly related to recreational use impairment. The TSI rating system is scaled to place a mesotrophic (medium fertility level) lake on the scale between 40 and 50, and high and low fertility lakes (eutrophic and oligotrophic) toward the high and low ends of the TSI range, respectively. Characteristics of lakes in different trophic status categories are listed below with their respective TSI ranges:

1. **Oligotrophic**—[$20 \leq TSI \leq 38$] clear, low productivity lakes, with total phosphorus concentrations less than or equal to 10 µg/L, chlorophyll *a* concentrations less than or equal to 2 µg/L, and Secchi disc transparencies greater than or equal to 4.6 meters (15 feet).

2. **Mesotrophic**—[$38 < TSI \leq 50$] intermediate productivity lakes, with 10 to 25 µg/L of total phosphorus, 2 to 8 µg/L of chlorophyll *a*, and Secchi disc measurements of 2 to 4.6 meters (6 to 15 feet).

3. **Eutrophic**—[$50 < TSI \leq 62$] high productivity lakes relative to a basic natural level, with 25 to 57 µg/L of phosphorus, 8 to 26 µg/L of chlorophyll *a*, and Secchi disc measurements of 0.85 to 2 meters (2.7 to 6 feet).

4. **Hypereutrophic**—[$62 < TSI \leq 80$] extremely productive lakes which are highly eutrophic, disturbed and unstable (i.e., fluctuating in their water quality on a daily and seasonal scale, producing gases, off-flavor, and toxic substances, experiencing periodic anoxia and fish kills, etc), with total phosphorus concentrations greater than 57 µg/L, chlorophyll *a* concentrations greater than 26 µg/L, and Secchi disc measurements less than 0.8 meters (less than 2.7 feet).

The RPBCWD goals for Lake Lucy include the following:

1. The **Water Quality Goal** for Lake Lucy is a TSI_{SD} score of 57 or lower, reflecting the Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) policy of non-degradation of current lake water quality

conditions. This goal is attainable only with recommended BMPs throughout the Lake Lucy watershed, as described in this use attainability analysis.

2. The **Recreation Goal for Lake Lucy** is to achieve full support of fishing activities and maintain waterfowl habitat. This goal is attainable with recommended BMPs throughout the Lake Lucy watershed and in-lake management of Lake Lucy's fishery, which include the BMPs prescribed for water quality as well as other management options described in this use attainability analysis.

3. The **Aquatic Communities Goal for Lake Lucy** is to maintain an MDNR-ecological class 42 rating, with a TSI_{SD} of 62. This goal may be better expressed as a non-degradation water quality goal because water quality directly affects the aquatic communities in Lake Lucy. This goal is attainable with recommended BMPs throughout the Lake Lucy watershed, which include the BMPs prescribed for water quality as well as other management options described in this use attainability analysis.

4. The **Water Quantity Goal for Lake Lucy** is to provide sufficient water storage during a regional flood. This goal is attainable with no action.

5. The **Wildlife Goal for Lake Lucy** is to protect existing, beneficial wildlife uses. This goal is attainable with no action.

The RPBCWD goals for Lake Ann include the following:

1. The **Water Quality Goal for Lake Ann** is a TSI_{SD} of 49 or lower, reflecting the RPBCWD policy of non-degradation of current lake water quality conditions. This goal is attainable, but only with recommended BMPs throughout the Lake Lucy and Lake Ann watersheds, as described in this use attainability analysis.

2. The **Recreation Goal for Lake Ann** is to achieve a fully-supporting use classification in accord with the "MPCA Use Support Classification for Swimming Relative to Carlson's Trophic State Index by Ecoregion," with a TSI_{SD} of less than or equal to 53. This goal is attainable with the recommended BMPs prescribed to meet Lake Ann's water quality goal.

3. The **Aquatic Communities Goal for Lake Ann** is to maintain an MDNR ecological class 24 rating, with a TSI_{SD} of 56. This goal may be better expressed as a non-degradation water quality goal because water quality directly affects the aquatic communities in Lake Ann. This goal is attainable with the recommended BMPs throughout the Lake Lucy and Lake Ann watersheds, which include the BMPs

prescribed to meet the water quality goal, as well as other management options described in this use attainability analysis.

4. The **Water Quantity Goal for Lake Ann** is to provide sufficient water storage during a regional flood. This goal is attainable with no action.

5. The **Wildlife Goal for Lake Ann** is to protect existing, beneficial wildlife uses. This goal is attainable with no action.

Water Quality Problem Assessment

Historical and Current Water Quality

Analysis of historical Lake Lucy and Lake Ann total phosphorus, chlorophyll *a* and Secchi disc transparency indicate significant variability from year to year in both lakes. It is difficult to establish a significant trend in the data.

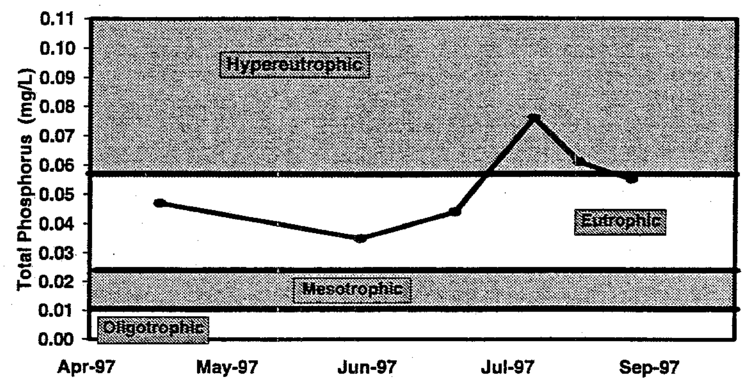
Figure EX-1 summarizes the seasonal changes in concentration of total phosphorus, chlorophyll *a*, and Secchi disc transparency for Lake Lucy during 1997. The data are shown compared to a standardized lake rating system. Based on summer average total phosphorus (0.054 mg/L) chlorophyll *a* (24.6 μg/L) and Secchi disc transparency (3.1 m) the lake is considered eutrophic.

Figure EX-2 summarizes the seasonal changes in concentration of total phosphorus, chlorophyll *a*, and Secchi disc transparency for Lake Ann during 1997. The data are shown compared to a standardized lake rating system. Based on summer average total phosphorus (0.024 mg/L) and Secchi disc transparency (2.4 m) the lake is considered mesotrophic. However, the average summer chlorophyll a concentration (8.7 μg/L) falls in the eutrophic category.

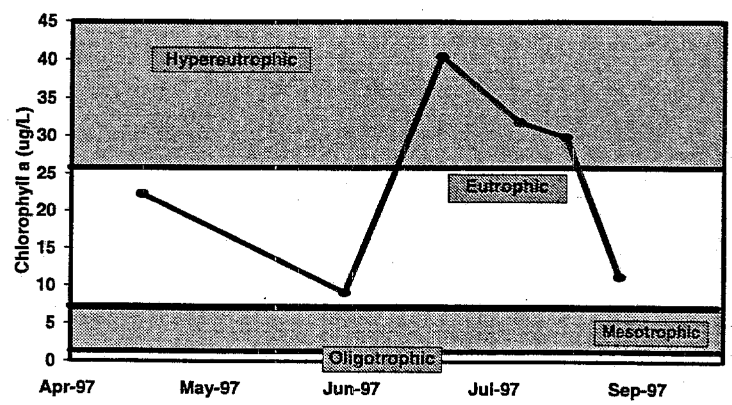
Watershed Runoff Pollution

Although, internal loading (phosphorus release from the bottom sediment) contributes to water quality degradation during late summer, computer simulations and observed water quality data indicate that phosphorus inputs to the lakes are mostly from watershed and atmospheric loads (external sources).

Lake Lucy: Epilimnetic (0-2 Meters) Total Phosphorus Concentration



Lake Lucy: 1996-1997 Epilimnetic Chlorophyll Concentrations



Lake Lucy: 1996-1997 Secchi Disc Transparencies

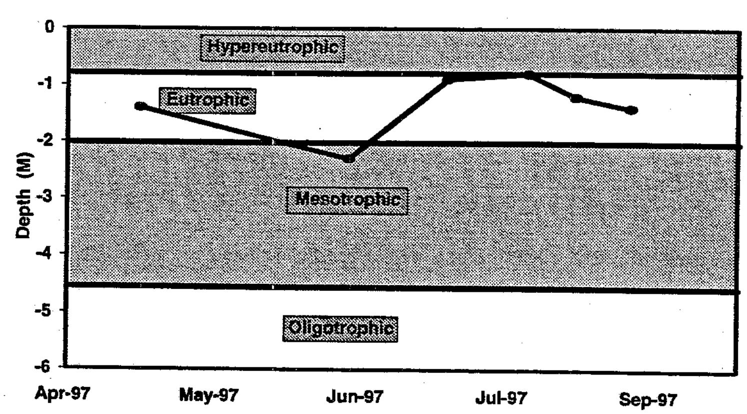


Figure EX-1:
Seasonal Changes in Concentrations of Total Phosphorus and Chlorophyll a and Secchi Disc Transparencies in Lake Lucy

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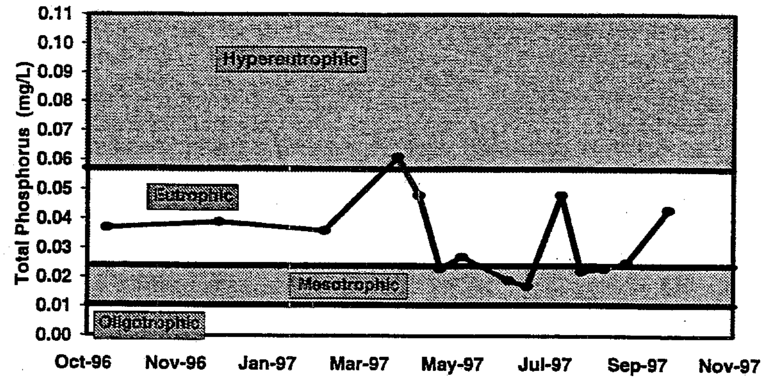
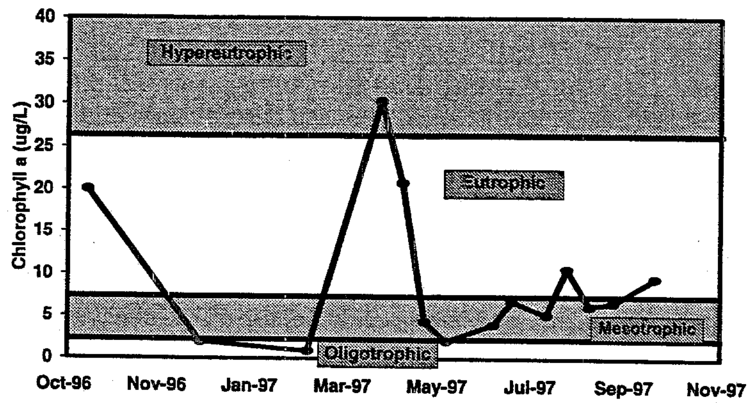
Lake Ann: Epilimnetic (0-2 Meters) Total Phosphorus Concentration



Lake Ann: 1996-1997 Epilimnetic Chlorophyll Concentrations



Lake Ann: 1996-1997 Secchi Disc Transparencies

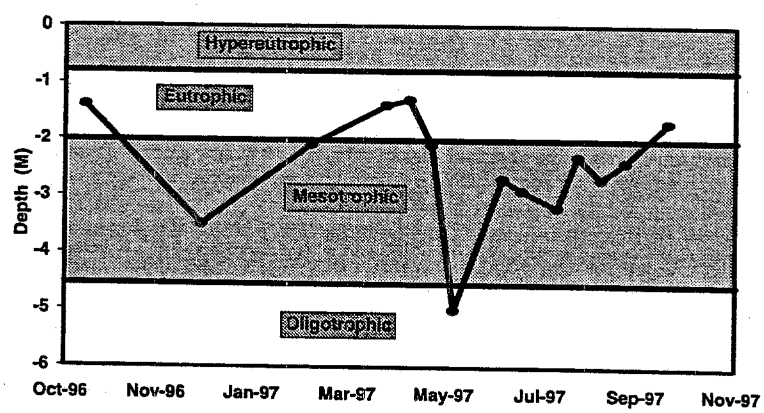


Figure EX-2:
Seasonal Changes in Concentrations of Total Phosphorus and Chlorophyll a and Secchi Disc Transparencies in Lake Ann

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Land use information shows that the lakes' watersheds are currently only partially developed (urbanized). However, more development is projected within the watersheds. As the watersheds become more urbanized, phosphorus loadings to the lakes will likely increase, worsening lake water quality. If no best management practices are implemented in the watersheds to counteract the effects of this future development, the water quality in neither Lake Lucy nor Lake Ann will meet the District's goals.

Figures EX-3, EX-4 and EX-5 show the existing and future land uses in the Lake Lucy and Lake Ann watersheds. Currently, the northern half of the Lake Lucy watershed is developed (urbanized). The urbanized area consists mostly of very low to low density residential developments. The current undeveloped areas are parks, natural open spaces and wetlands. Future (Year 2020) land use will consist primarily of low density residential developments and wetlands, assuming that the wetlands in the watershed are preserved.

The Lake Ann watershed currently consists of mostly natural open space and park land. Approximately half of this land will be developed as low to medium density residential land under the Year 2020 projections.

Computer simulations of runoff water quality under existing and future land uses indicate that the total phosphorus load could increase by ~50% to Lake Lucy and by 110% to Lake Ann as development reaches completion.

There are seven major watershed conveyance networks that act as sources of phosphorus to Lake Lucy; each conveyance system is named after the terminating watershed in each network: LU-A1.11, LU-A2.6b, LU-A2.3, LU-A3.5, LU-A4.1, LU-A4.2, LU-A5.15. Lake Lucy is the major source of phosphorus to Lake Ann, although Lake Ann's immediate watershed also contributes some of the annual phosphorus load. Figure EX-6 shows the locations of each of these conveyance systems. Figure EX-7 shows the contribution of TP load (in terms of percent of annual load in 1997 under future land use conditions) from each conveyance network.

Aquatic Plant Communities

Macrophyte (i.e., aquatic plant) surveys were conducted during June and August 1997. The current macrophyte communities in Lake Lucy and Lake Ann are diverse and healthy. However, some areas of Lake Lucy occasionally experience dense growths of curly-leaf pondweed. Curly-leaf pondweed is an undesirable non-native species. It frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. A dense growth also creates a refuge for small fish, making it difficult for larger fish, such as bass, to find and capture the small fish they need for food. However, the curly-leaf pondweed growths in Lake Lucy are not yet significant enough to cause great concern.

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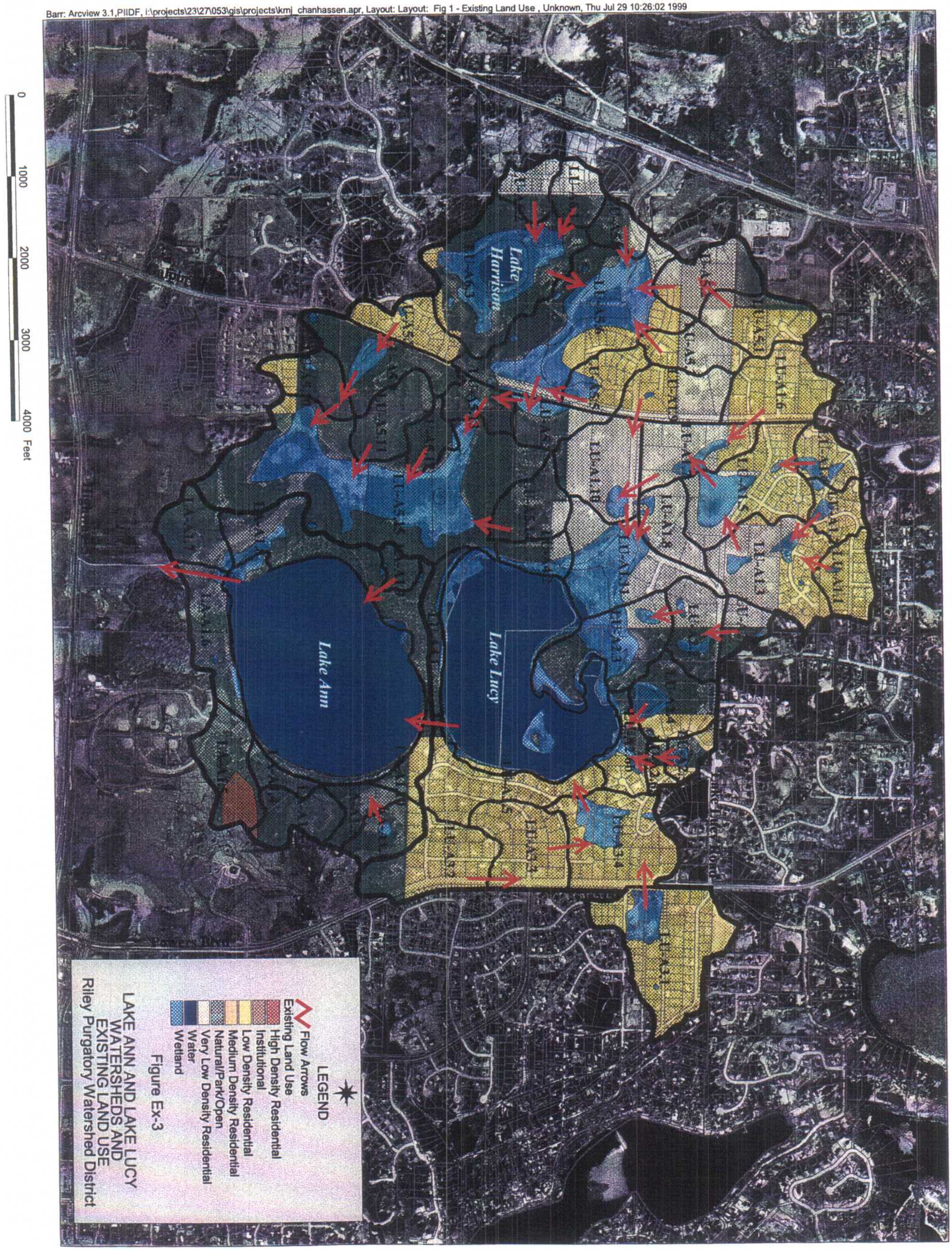

Figure Ex-3

LAKE ANN AND LAKE LUCY
WATERSHEDS AND
EXISTING LAND USE
Riley Purgatory Watershed District

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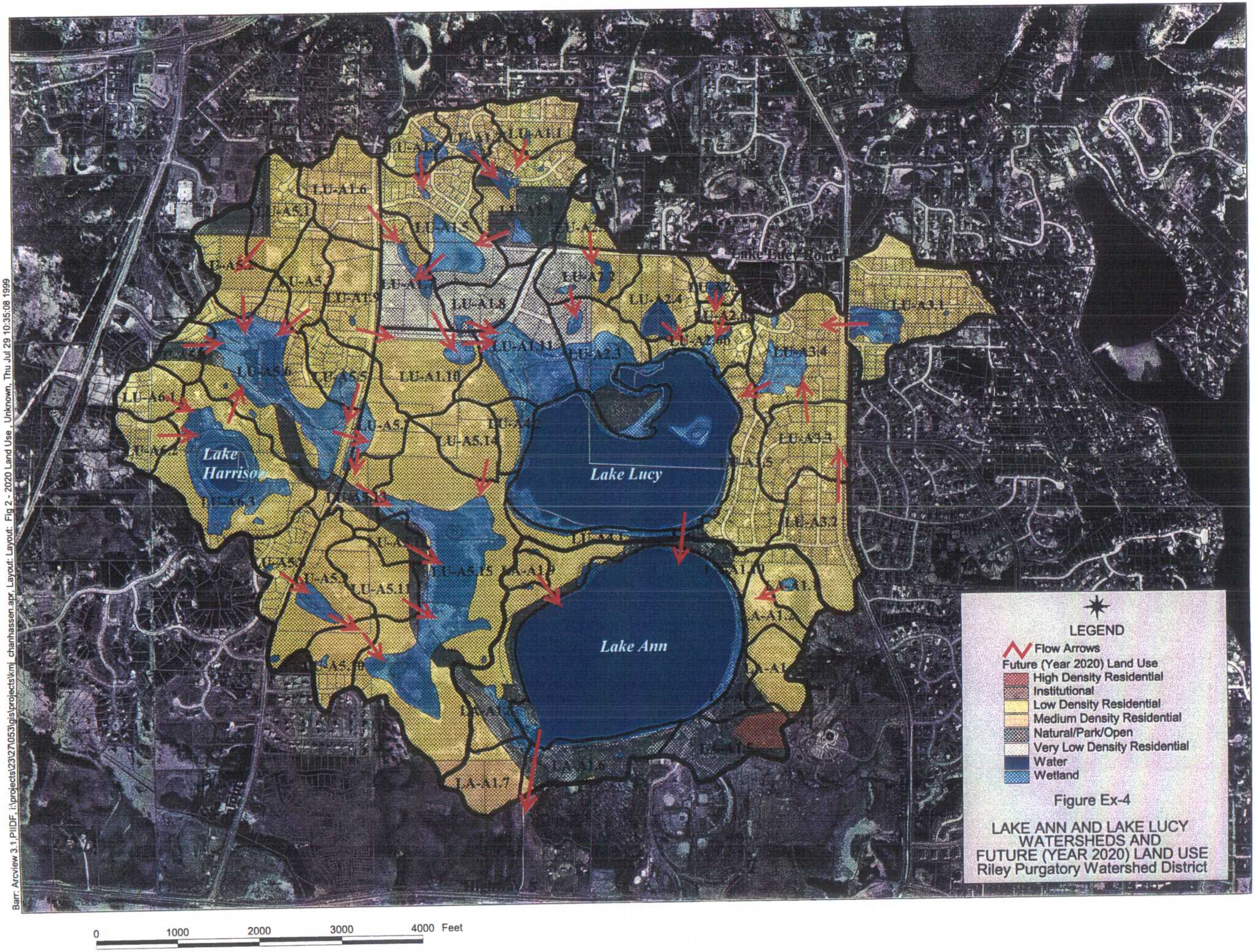
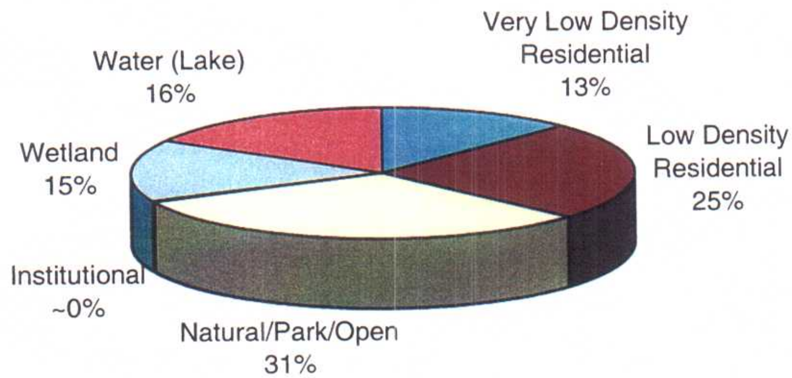


Figure Ex-4

LAKE ANN AND LAKE LUCY WATERSHEDS AND FUTURE (YEAR 2020) LAND USE
Riley Purgatory Watershed District

Existing Land Uses in the Lake Lucy and Lake Ann Watersheds



Future (Year 2020) Land Uses in the Lake Lucy and Lake Ann Watersheds
(assuming that all wetlands are preserved)

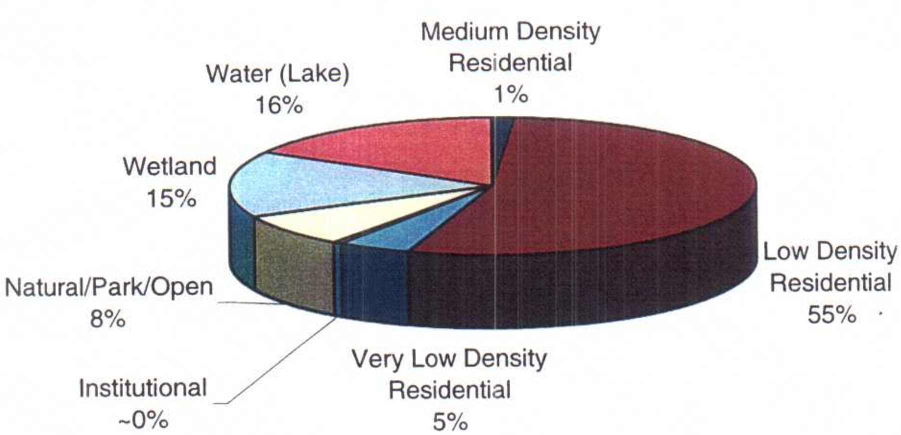
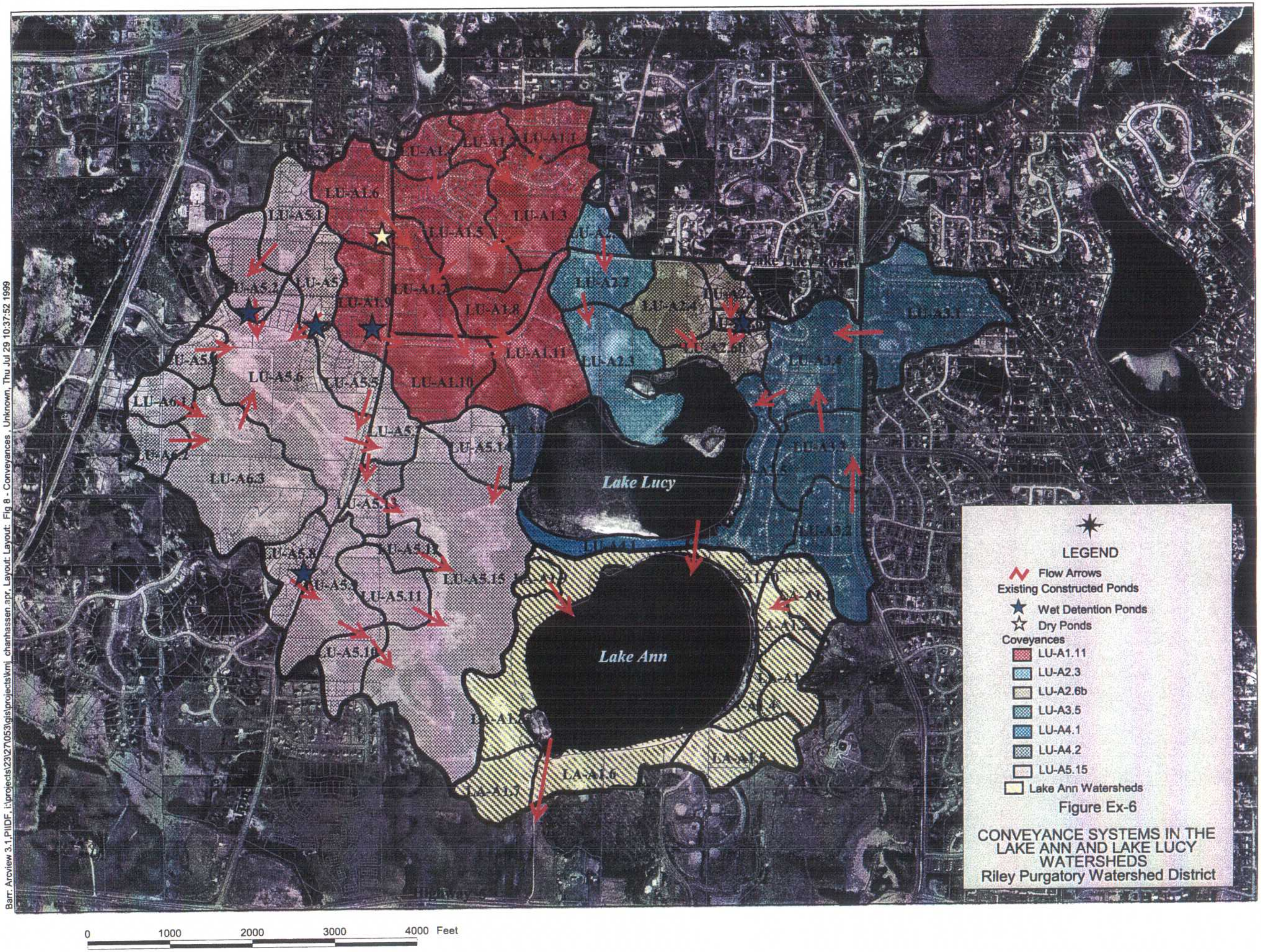
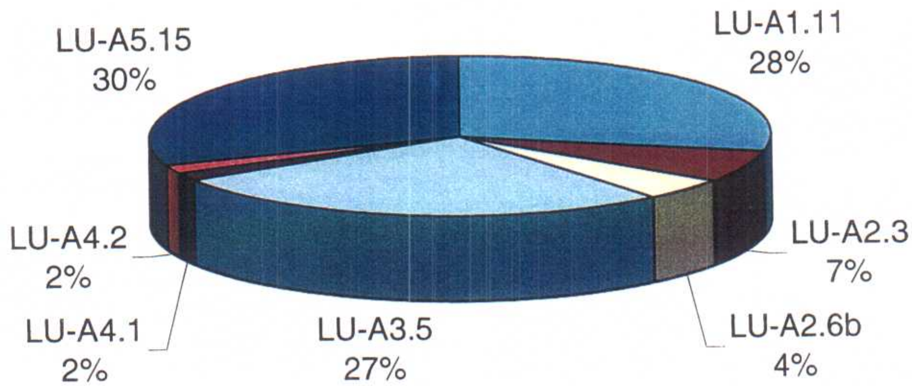


Figure EX-5: Percentages of Land Use Types in the Future (Year 2020) and Existing Lake Lucy and Lake Ann Watersheds


Barr: Arcview 3.1,PIIDF, i:\projects\23\27\053\gis\projects\km_chanhassen.apr, Layout: Layout: Fig 8 - Conveyances , Unknown, Thu Jul 29 10:37:52 1999
Lake Lucy
Lake Ann
LU-A1.6
LU-A1.5
LU-A1.3
LU-A1.2
LU-A1.9
LU-A1.8
LU-A1.11
LU-A1.10
LU-A2.7
LU-A2.4
LU-A2.3
LU-A3.1
LU-A3.4
LU-A3.3
LU-A3.2
LU-A5.1
LU-A5.6
LU-A5.5
LU-A5.14
LU-A5.12
LU-A5.8
LU-A5.15
LU-A5.11
LU-A5.10
LU-A6.3
LA-A1.6
LA-A1.7
LEGEND
Flow Arrows
Existing Constructed Ponds
Wet Detention Ponds
Dry Ponds
Coveyances
LU-A1.11
LU-A2.3
LU-A2.6b
LU-A3.5
LU-A4.1
LU-A4.2
LU-A5.15
Lake Ann Watersheds
Figure Ex-6
CONVEYANCE SYSTEMS IN THE LAKE ANN AND LAKE LUCY WATERSHEDS
Riley Purgatory Watershed District
0
1000
2000
3000
4000 Feet

Lake Lucy



Lake Ann

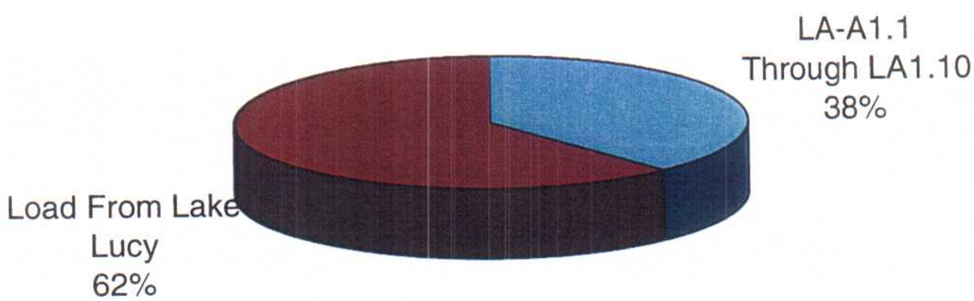


Figure EX-7: Conveyance system contributions to the 1997 annual phosphorus loads to Lake Lucy and Lake Ann as predicted by P8 modeling of the watersheds under future land use conditions.

Aquatic Ecosystems

As in previous years, blue-green and green algae were generally the dominant types of phytoplankton observed in 1997. Blue-green algae were especially dominant in Lake Lucy. Green algae are edible to zooplankton and serve as a valuable food source. Blue-green algae are considered a nuisance type of algae because they: are generally inedible to fish, waterfowl, and most zooplankters; float at the lake surface in expansive algal blooms; may be toxic to animals when occurring in large blooms; and can disrupt lake recreation, since they are most likely to be present during the summer months.

The 1997 Lake Lucy and Lake Ann zooplankton community was lower than those observed in earlier sampling events, but not to a significant degree.

The fisheries in both lakes are considered to be healthy (Ellison, 1999). Lake Lucy does experience some occasional winterkills, however, and has a large number of small black bullheads. Lake Ann is considered to be an excellent fishing lake, with above-average yields of northern pike (according to the MDNR's 1995 fisheries survey). Although both lakes currently meet the RPBCWD goals for aquatic communities, future land use conditions may change the quality of the fisheries in the lakes.

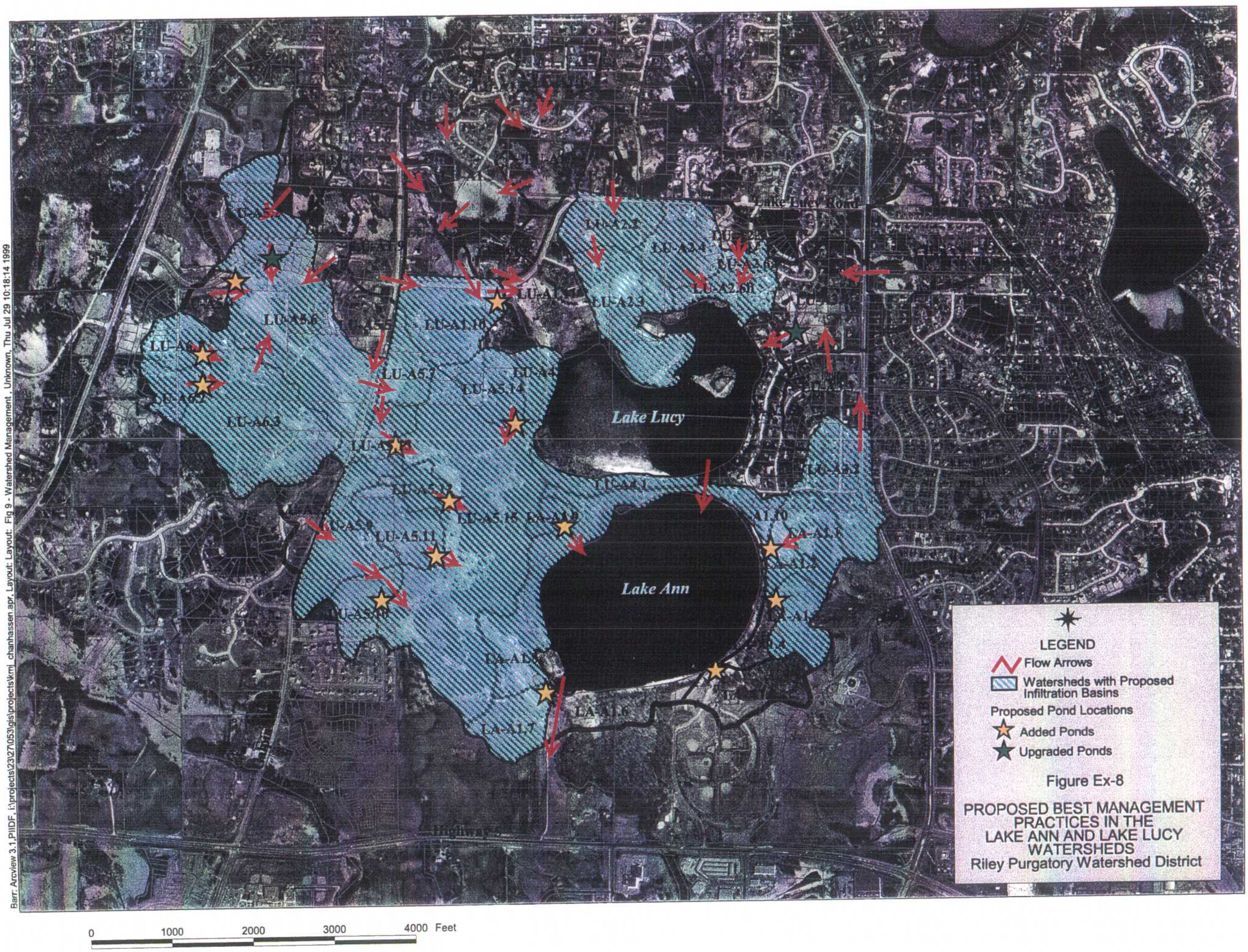
Recommended Best Management Practices in the Lake Lucy and Lake Ann Watersheds

Several BMPs are recommended in order to meet or exceed the District's goals for Lake Lucy and Lake Ann. The proposed locations of the watershed BMPs described below are shown in Figure EX-8.

Lake Lucy

Several management recommendations involve improvements in the Lake Lucy watershed.

- Preservation of all existing wetlands in the Lake Lucy watershed. If voluntary or required protections for the wetlands are not likely to succeed, the estimated cost of purchasing these areas for preservation would be at current market value.
- Upgrading two ponds in the Lake Lucy watershed to provide more wet detention for stormwater treatment. Design and construction of these upgraded ponds would cost approximately $148,300.
- Adding seven ponds in the Lake Lucy watershed in areas that contribute significant particulate phosphorus loads to the lake. Design and construction of these added ponds would cost approximately $206,000.


Lake Lucy
Lake Ann
Lake Lucy Road
LEGEND
Flow Arrows
Watersheds with Proposed Infiltration Basins
Proposed Pond Locations
Added Ponds
Upgraded Ponds
Figure Ex-8
PROPOSED BEST MANAGEMENT PRACTICES IN THE LAKE ANN AND LAKE LUCY WATERSHEDS
Riley Purgatory Watershed District
0
1000
2000
3000
4000 Feet
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LAKE LUCY
Costs to Meet or Exceed Goals

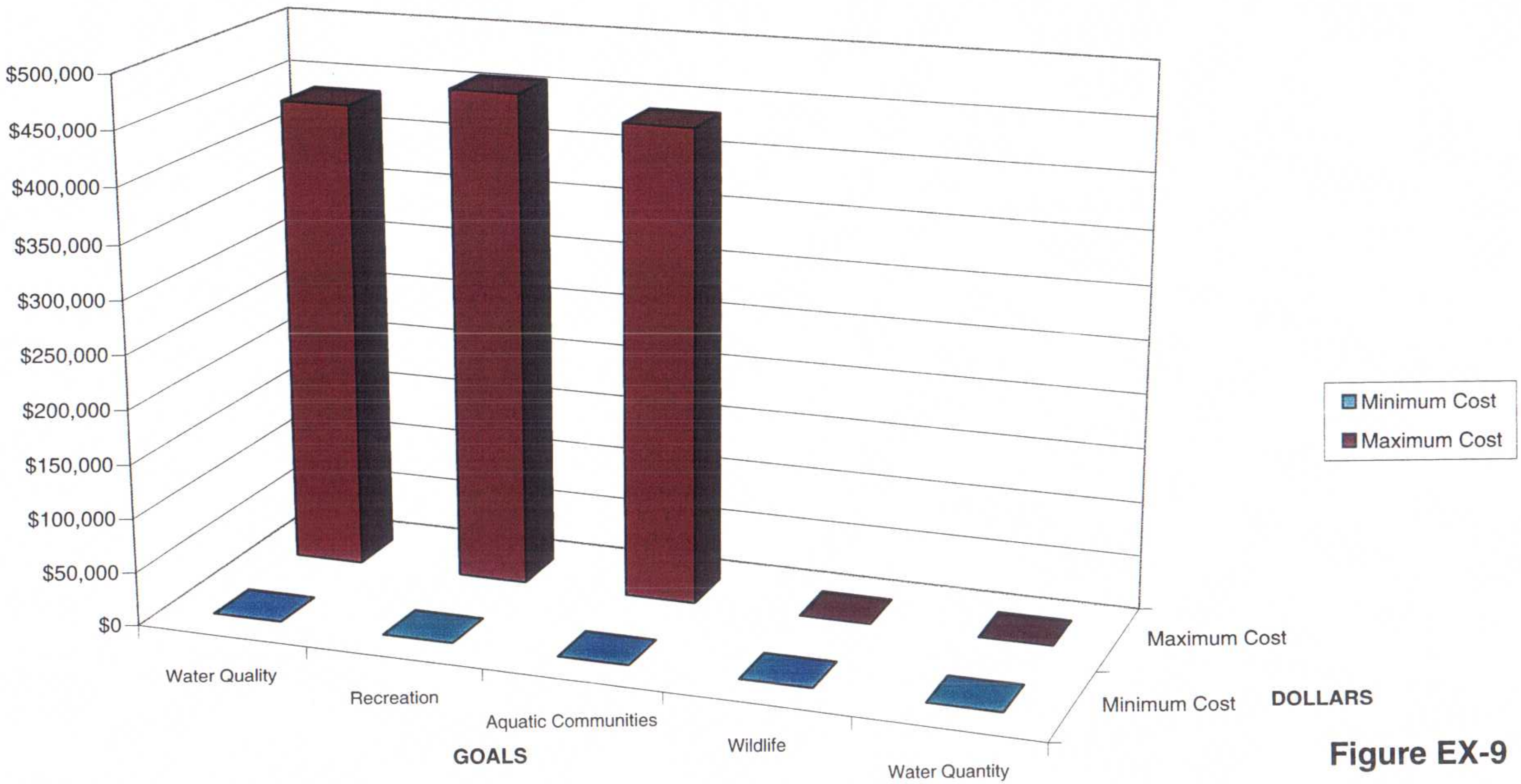

Figure EX-9

"Minimum Cost" is the cost of the option that just meets each of the goals set for Lake Lucy.
"Maximum Cost" is the cost of the most expensive option analyzed in this study that exceeds each of the goals set for Lake Lucy.
Between these options are others that offer different degrees of success in meeting or exceeding the goals set for Lake Lucy.
It is important to note that all of the costs for meeting the Water Quality, Recreation and Aquatic Communities goals DO NOT include the cost of wetland aquisition.
If voluntary or required wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

P:\23\27\053\ela\costs.xls

- Providing infiltration basins throughout the Lake Lucy watershed in areas that experience a significant change in impervious area between existing and future (Year 2020) land use conditions. Design and construction of these infiltration basins would cost approximately $50,000.

Other management options within Lake Lucy itself are also recommended:

- Managing the fisheries by stocking sport fish after winterkills (~$2,500), employing commercial anglers to remove rough fish (~$1,000 per day), and installing a fishing pier (~$18,000 for an 84-foot-long, T-shaped pier). These estimated costs were provided by the DNR.
- Managing the lake's macrophytes by continuing to survey communities in order to detect nuisance, non-native growths. A typical macrophyte survey costs approximately $1,200 per lake.

Lake Ann

Several management recommendations involve improvements in the Lake Lucy and Lake Ann watersheds.

- Preservation of all existing wetlands in the Lake Lucy and Lake Ann watersheds. If voluntary or required protections for the wetlands are not likely to succeed, the estimated cost of purchasing these areas for preservation would be at current market value.
- Upgrading two ponds in the Lake Lucy watershed to provide more wet detention for stormwater treatment. Design and construction of these upgraded ponds would cost approximately $148,300.
- Adding seven ponds in the Lake Lucy watershed and five ponds in the Lake Ann watershed in areas that contribute significant particulate phosphorus loads to each lake. Design and construction of these added ponds would cost approximately $349,000.
- Providing infiltration basins throughout the Lake Lucy and Lake Ann watersheds in areas that experience a significant change in impervious area between existing and future (Year 2020) land use conditions. Design and construction of these infiltration basins would cost approximately $50,000 in the Lake Lucy watershed and $13,500 in the Lake Ann watershed.

Another management option within Lake Ann itself is also recommended:

- Managing the lake's macrophytes by continuing to survey communities in order to detect nuisance, non-native growths. A typical macrophyte survey costs approximately $1,200 per lake.

Recommended Goal Achievement Alternatives for Lake Lucy and Lake Ann

Lake Lucy

Model simulations indicate that wet climate conditions place the greatest strain upon the water quality of Lake Lucy because the phosphorus loadings are greatest under these conditions. There are four recommended alternatives that will achieve all District goals under all modeled climatic conditions. Assuming average, dry or calibration year (1997) conditions, which place a lesser strain upon the water quality of Lake Lucy, another less stringent alternative will achieve all District goals. Consequently, a total of five recommended alternatives were considered to achieve all District goals. The water quality benefits and costs of the five alternatives are presented in Table EX-1.

Table EX-1 Benefits and Costs of Five Goal Achievement Alternatives for Lake Lucy

Alternative	Trophic State Index (TSI) Value					Estimated Cost (Dollars)
	District Goal	Wet Year (1983; 41 inches of precipitation)	Model Calibration (1997; 34 inches of precipitation)	Average Year (1995; 27 inches of precipitation)	Dry Year (1988; 19 inches of precipitation)	
1: Preserve All Wetlands	≤ 57	58*	55	57	57	$0**
2: Preserve All Wetlands Upgrade 1 Detention Pond (LU-A3.4), Add 1 Detention Pond	≤ 57	57	54	56	57	$195,000**
3: Preserve All Wetlands Upgrade 2 Detention Ponds, Add 7 Detention Ponds	≤ 57	57	54	55	56	$354,000**
4: Preserve All Wetlands Upgrade 2 Detention Ponds, Add 7 Detention Ponds Store Stormwater in Infiltration Basins	≤ 57	55	52	53	55	$404,000**
5: Preserve All Wetlands Upgrade 2 Detention Ponds, Add 7 Detention Ponds Store Stormwater in Infiltration Basins, Manage***	≤ 57	55	52	53	55	$427,000**

* Does not meet the District's Water Quality Goal.
** This cost does not include the cost of aquiring wetlands for preservation. If required or voluntary wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.
*** "Manage" includes macrophyte surveys, fish stocking after winterkills, rough fish removal and installation of a fishing pier.

Alternatives 2, 3, 4, and 5 in Table EX-1 achieve all district goals under all climatic conditions, including wet conditions. Figure EX-9 compares the minimum and maximum costs of the alternatives. Because Alternative 5 offers the highest chance of success in meeting the District's goals in every climatic condition, and because these BMPs are necessary in order for Lake Ann to meet its own goals under every climatic condition, this is the recommended alternative.

Lake Ann

It has been determined that average climate conditions place the greatest strain upon the water quality of Lake Ann because the phosphorus load/water load balance results in the highest in-lake phosphorus concentration under these conditions. There are two recommended alternatives that will achieve all District goals. Assuming wet, dry or calibration year (1997) conditions, which place a lesser strain upon the water quality of Lake Ann, another less stringent alternative will achieve all District goals. Consequently, a total of three recommended alternatives were considered to achieve all District goals. The water quality benefits and costs of the three alternatives are presented in Table EX-2.

Table EX-2 Benefits and Costs of Five Goal Achievement Alternatives for Lake Ann

Alternative	Trophic State Index (TSI) Value					Estimated Cost (Dollars)
	District Goal	Wet Year (1983; 41 inches of precipitation)	Model Calibration (1997; 34 inches of precipitation)	Average Year (1995; 27 inches of precipitation)	Dry Year (1988; 19 inches of precipitation)	
1: Preserve All Wetlands Upgrade 2 Detention Ponds Add 12 Detention Ponds	≤ 49	49	47	50*	49	$414,000**
2: Preserve All Wetlands Upgrade 2 Detention Ponds, Add 12 Detention Ponds Store Stormwater in Infiltration Basins	≤ 49	48	46	49	46	$478,000**
3: Preserve All Wetlands Upgrade 2 Detention Ponds, Add 12 Detention Ponds Store Stormwater in Infiltration Basins, Manage***	≤ 49	48	46	49	46	$479,000**

* Does not meet the District's Water Quality Goal.
** This cost does not include the cost of aquiring wetlands for preservation. If required or voluntary wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.
*** "Manage" includes macrophyte surveys

LAKE ANN
Costs to Meet or Exceed Goals

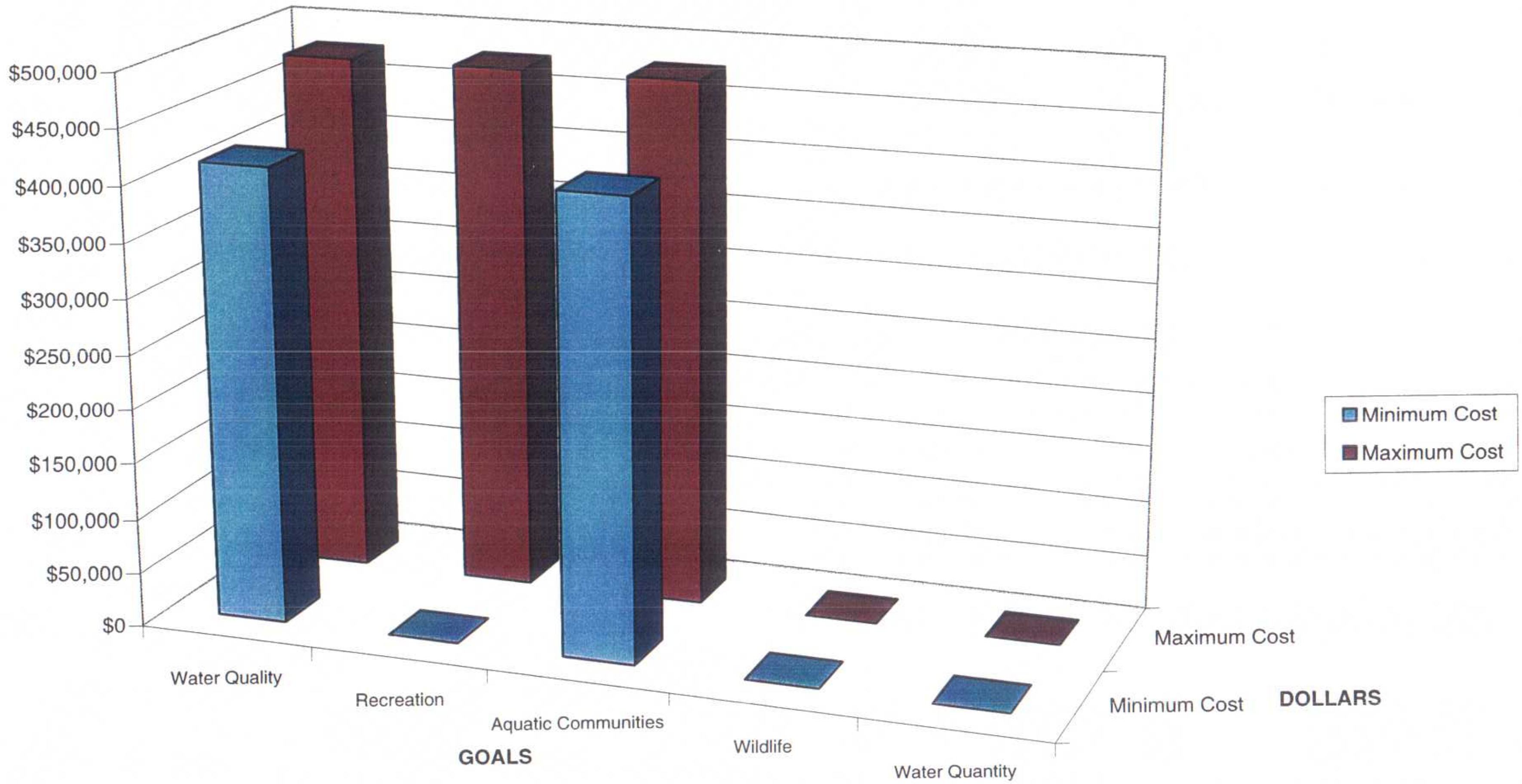

Figure EX-10

"Minimum Cost" is the cost of the option that just meets each of the goals set for Lake Ann.
"Maximum Cost" is the cost of the most expensive option analyzed in this study that exceeds each of the goals set for Lake Ann.
Between these options are others that offer different degrees of success in meeting or exceeding the goals set for Lake Ann.
It is important to note that all of the costs for meeting the Water Quality, Recreation and Aquatic Communities goals DO NOT include the cost of wetland aquisition.
If voluntary or required wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

Alternatives 2 and 3 in Table EX-2 achieve all district goals under all climatic conditions, including average conditions. Figure EX-10 compares the minimum and maximum costs of the alternatives. Because alternative 3 offers the highest chance of success in meeting the District's goals in every climatic condition, this is the recommended alternative.

Lake Lucy and Lake Ann Use Attainability Analysis

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1.0 Surface Water Resources Data

The approved *Riley-Purgatory-Bluff Creek Watershed District, Water Management Plan*, Barr Engineering Company, 1996 (Plan), inventoried and assessed Lake Lucy and Lake Ann. The Plan articulated five specific goals for both lakes. These goals address:

- Water Quality
- Recreation
- Aquatic Communities
- Water Quantity
- Wildlife

This report:

(1) evaluates the existing and potential beneficial uses intended in these goals;

(2) contains an analysis of the factors that potentially impair or limit those beneficial uses, particularly problems identified in the Plan;

(3) expands upon specific aspects of the inventory and assessment of Lake Lucy and Lake Ann contained in the Plan.

A use attainability analysis of Lake Lucy and Lake Ann was completed to provide the scientific foundation for a lake-specific BMP that will maintain or attain the existing and potential beneficial uses of the lakes. A use attainability analysis evaluates existing and potential beneficial uses of a water resource. "Use attainment" refers to the designated beneficial uses, such as swimming and fishing. Factors that potentially impair or limit existing beneficial uses, including problems identified in the inventory and assessment, are investigated in the use attainability analysis. Lake analyses rely on previously-collected field data and continue with watershed evaluations using water quality modeling. Lake Lucy and Lake Ann essentially function together as one hydraulic unit. Consequently, the water quality of Lake Lucy greatly affects that of Lake Ann. For these reasons, Lake Lucy and Lake Ann were modeled, studied and presented together for this use attainability study.

The main tool for the technical analysis is an advanced water quality model that predicts the amount of pollutants that reach a lake via stormwater runoff. Calibrating the model to a lake requires an accurate measurement of land use and lake water quality. Impacts of upland detention and infiltration basins are included in the model.

An important component of the use attainability analysis is public participation. A technical advisory committee and/or citizens advisory committee will be formed to provide input on use attainment for Lake Lucy and Lake Ann. In addition, citizens in both watersheds will be notified of meetings through the District's published newsletter and they will be encouraged to become involved in the process.

1.1 Land Use

All land use practices within a lake's watershed impact the lake and determine its water quality. Impacts result from the export of sediment and nutrients, primarily phosphorus, to a lake from its watershed. Each land use contributes a different quantity of phosphorus to the lake, thereby affecting the lake's water quality differently. Land uses in the Lake Lucy and Lake Ann watersheds have changed over time and will continue to change as development continues. Lake water quality changes have been correlated with land use changes. Future and existing land uses in the Lake Lucy and Lake Ann watersheds are discussed in the following paragraphs.

Existing land uses were identified with aerial photos and verified in the field. Watershed delineations from the *City of Chanhassen Surface Water Management Plan* (Bonestroo Rosene Anderlik and Associates, 1994) were also field-verified and used in this study. This information was incorporated into ArcView, a GIS-based software to calculate the different types of land use associated within each subwatershed (Figure 1 and Table 1).

Currently, Lake Lucy's 993-acre watershed (including Lake Lucy) consists of:

- Very Low Density Residential (~ one house per acre)—156 acres
- Low Density Residential (2 to 3 houses per acre)—301 acres
- Natural/Park/Open —264 acres
- Wetland—184 acres
- Water (Lake Lucy and Harrison Lake)—88 acres

Table 1: Existing Land Uses in the Lake Lucy and Lake Ann Watersheds

Lake Lucy

Subwatershed	Very Low Density Residential (acres)	Low Density Residential (acres)	Natural/Park/Open (acres)	Wetland (acres)	Water (Lake) (acres)	Total (acres)
LU-A1.1	0	13	0	0	0	14
LU-A1.2	0	8	0	1	0	10
LU-A1.3	16	14	0	3	0	33
LU-A1.4	0	8	0	2	0	10
LU-A1.5	7	19	0	8	0	33
LU-A1.6	0	22	0	0	0	23
LU-A1.7	14	4	0	3	0	20
LU-A1.8	12	0	0	1	0	13
LU-A1.9	11	8	0	0	0	19
LU-A1.10	21	0	2	2	0	25
LU-A1.11	14	0	0	18	0	32
LU-A2.1	4	0	3	0	0	7
LU-A2.2	8	0	7	2	0	17
LU-A2.3	4	0	13	14	0	31
LU-A2.4	0	5	11	4	0	19
LU-A2.5	0	3	2	1	0	6
LU-A2.6a	0	4	2	2	0	8
LU-A2.6b	0	3	5	6	0	14
LU-A3.1	0	37	0	6	0	43
LU-A3.2	0	20	6	0	0	26
LU-A3.3	0	23	0	0	0	23
LU-A3.4	0	28	0	6	0	34
LU-A3.5	0	23	1	1	0	25
LU-A4.1	0	0	7	2	0	9
LU-A4.2	2	0	4	3	0	8
LU-A5.1	4	10	3	0	0	18
LU-A5.2	12	2	4	0	0	17
LU-A5.3	7	5	0	0	0	13
LU-A5.4	2	0	5	1	0	8
LU-A5.5	1	9	0	3	0	13
LU-A5.6	3	11	17	28	0	60
LU-A5.7	2	0	6	2	0	11
LU-A5.8	0	13	0	0	0	13
LU-A5.9	0	1	19	3	0	24
LU-A5.10	0	3	9	0	0	13
LU-A5.11	0	0	16	0	0	16
LU-A5.12	0	0	7	0	0	8
LU-A5.13	0	0	9	1	0	10
LU-A5.14	2	0	13	0	0	15
LU-A5.15	0	1	62	41	0	104
LU-A6.1	5	0	5	0	0	10
LU-A6.2	6	0	3	0	0	9
LU-A6.3	0	2	26	18	4	51
Lake Lucy					84	84
Total	**156**	**301**	**267**	**181**	**88**	**993**

Lake Ann

Subwatershed	Low Density Residential (acres)	Natural/Park/Open (acres)	Institutional (acres)	Wetland (acres)	Water (acres)	Total (acres)
LA-A1.1	2	9	0	1		11
LA-A1.2	0	9	0	0		9
LA-A1.3	0	14	0	0		14
LA-A1.4	0	5	0	0		5
LA-A1.5	0	14	5	0		19
LA-A1.6	0	18	0	3		21
LA-A1.7	0	14	0	1		14
LA-A1.8	0	21	0	3		23
LA-A1.9	0	4	0	0		5
LA-A1.10	3	13	0	1		17
Lake Ann					117	117
Total	**6**	**119**	**5**	**8**	**117**	**255**

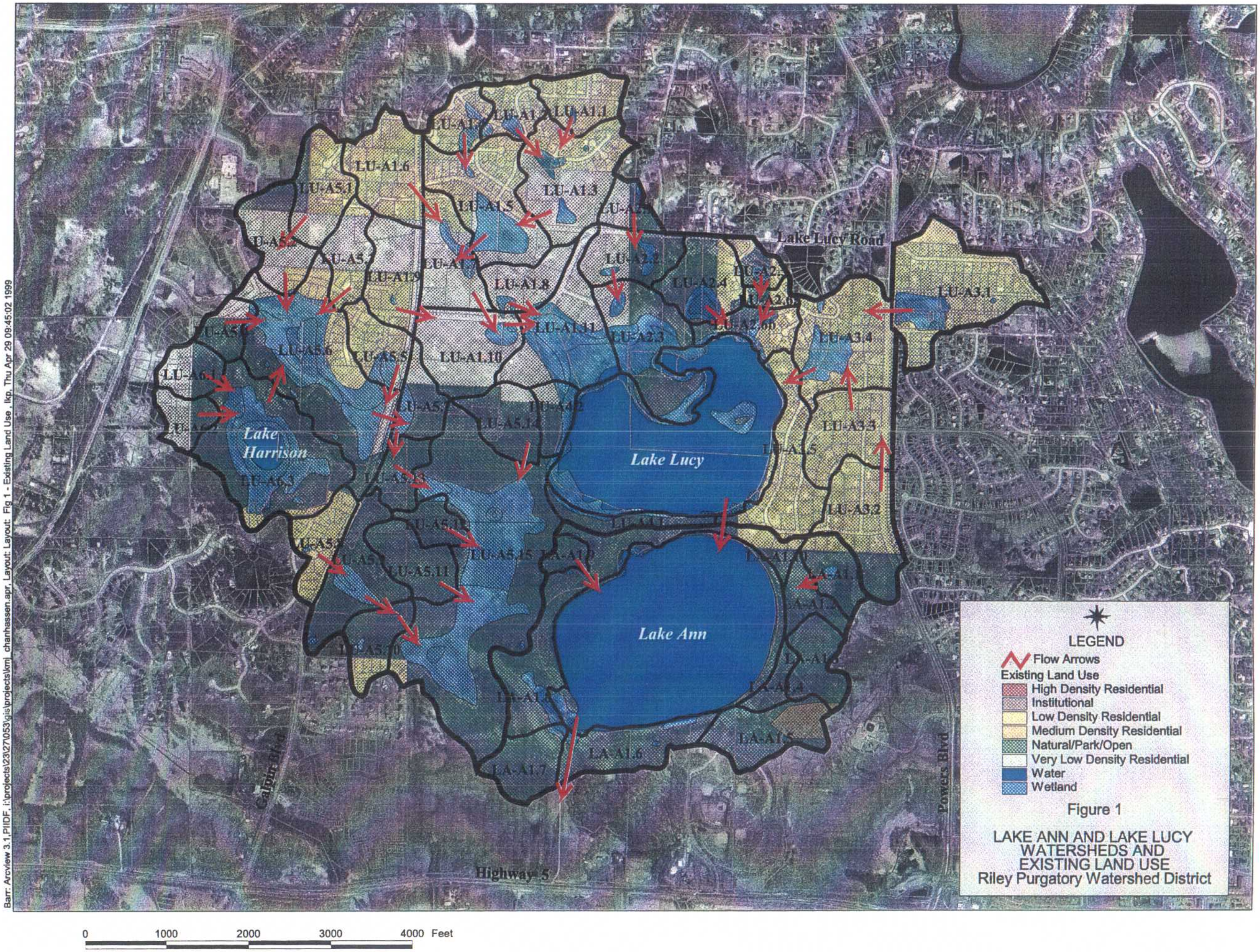

Figure 1

LAKE ANN AND LAKE LUCY WATERSHEDS AND EXISTING LAND USE
Riley Purgatory Watershed District

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Lake Ann's 255-acre watershed currently consists of:

- Low Density Residential—6 acres
- Natural/Park/Open—119 acres
- Institutional (School)—5
- Wetland—8 acres
- Water (Lake Ann)—117 acres

Future (Year 2020) land uses were provided in electronic format by the City of Chanhassen. Figure 2 and Table 2 show future land uses assuming that the existing wetlands (as defined by the NWI and verified in the field) are preserved. This assumption may or may not be realistic and will be discussed later in this report. Future land uses in the Lake Lucy watershed (assuming that wetlands are preserved) are:

- Medium Density Residential (~ 4 houses per acre)—4 acres
- Low Density Residential—614 acres
- Very Low Density Residential—57 acres
- Natural/Park/Open—46 acres
- Wetland—184 acres
- Water (Lake Lucy and Harrison Lake)—88 acres

Future land uses in the Lake Ann watershed (assuming the wetlands are preserved) are:

- Medium Density Residential—12 acres
- Low Density Residential—59 acres
- Natural/Park/Open—54 acres
- Institutional (School)—5
- Wetland—8 acres
- Water (Lake Ann)—117 acres

1.2 Major Hydrologic Characteristics

Lake Lucy has a 909-acre tributary watershed, a surface area of 84 acres (during a year of average precipitation), a maximum depth of approximately 18 feet, and a mean depth of 6.9 feet. Lake Ann has a 138-acre tributary watershed, a surface area of 117 acres (during a year of average precipitation), a maximum depth of approximately 40 feet, and a mean depth of 16.9 feet.

The lakes' volumes, outflow volumes, and hydrologic residence times vary with climatic conditions (Table 3).

Table 2: Future (Year 2020) Land Uses in the Lake Lucy and Lake Ann Watersheds

Lake Lucy

Subwatershed	Medium Density Residential (acres)	Low Density Residential (acres)	Very Low Density Residential (acres)	Institutional (acres)	Natural/Park/Open (acres)	Wetland (acres)	Water (Lake) (acres)	Total (acres)
LU-A1.1	0	13	0	0	0	0	0	14
LU-A1.2	0	8	0	0	0	1	0	10
LU-A1.3	0	15	2	0	13	3	0	33
LU-A1.4	0	8	0	0	0	2	0	10
LU-A1.5	0	20	5	0	0	8	0	33
LU-A1.6	0	22	0	0	0	0	0	23
LU-A1.7	0	4	13	0	0	3	0	20
LU-A1.8	0	0	12	0	0	1	0	13
LU-A1.9	0	18	1	0	0	0	0	19
LU-A1.10	0	20	3	0	0	2	0	25
LU-A1.11	0	5	9	0	0	17	0	31
LU-A2.1	0	6	0	0	1	0	0	7
LU-A2.2	0	6	8	0	0	2	0	17
LU-A2.3	0	12	5	0	0	15	0	31
LU-A2.4	0	16	0	0	0	4	0	19
LU-A2.5	0	5	0	0	0	1	0	6
LU-A2.6a	0	6	0	0	0	2	0	8
LU-A2.6b	0	8	0	0	0	6	0	14
LU-A3.1	0	37	0	0	0	6	0	43
LU-A3.2	2	23	0	0	0	0	0	26
LU-A3.3	1	23	0	0	0	0	0	23
LU-A3.4	0	28	0	0	0	6	0	34
LU-A3.5	0	23	0	0	1	1	0	25
LU-A4.1	0	5	0	0	1	3	0	9
LU-A4.2	0	5	0	0	0	3	0	8
LU-A5.1	0	14	0	0	4	0	0	18
LU-A5.2	0	13	0	0	4	0	0	17
LU-A5.3	0	13	0	0	0	0	0	13
LU-A5.4	0	5	0	0	3	1	0	8
LU-A5.5	0	10	0	0	0	3	0	13
LU-A5.6	0	25	0	0	6	28	0	60
LU-A5.7	0	8	0	0	0	2	0	11
LU-A5.8	0	13	0	0	0	0	0	13
LU-A5.9	0	20	0	0	0	3	0	24
LU-A5.10	0	12	0	0	0	0	0	13
LU-A5.11	0	14	0	0	2	0	0	16
LU-A5.12	0	4	0	0	3	0	0	8
LU-A5.13	0	7	0	0	2	1	0	10
LU-A5.14	0	15	0	0	0	0	0	15
LU-A5.15	1	57	0	0	5	41	0	104
LU-A6.1	0	10	0	0	0	0	0	10
LU-A6.2	0	9	0	0	0	0	0	9
LU-A6.3	0	27	0	0	1	18	4	51
Lake Lucy							84	84
Total	**4**	**614**	**57**	**0**	**46**	**184**	**88**	**993**

Lake Ann

Subwatershed	Medium Density Residential (acres)	Low Density Residential (acres)	Institutional (acres)	Natural/Park/Open (acres)	Wetland (acres)	Water (acres)	Total (acres)
LA-A1.1	0	11	0	0	1		11
LA-A1.2	0	8	0	1	0		9
LA-A1.3	0	12	0	1	0		14
LA-A1.4	0	1	0	5	0		5
LA-A1.5	0	0	5	14	0		19
LA-A1.6	1	0	0	16	3		20
LA-A1.7	11	2	0	1	1		14
LA-A1.8	0	10	0	10	3		23
LA-A1.9	0	4	0	0	0		5
LA-A1.10	0	11	0	6	1		17
Lake Ann						117	117
Total	**12**	**59**	**6**	**54**	**8**	**117**	**255**

Table 3: Lake Lucy and Lake Ann Estimated Volumes, Outflow Volumes and Hydrologic Residence Times During Varying Climatic Conditions

Lake Lucy

Climatic Condition (Water Year, Inches of Precipitation)	Lake Elevation (MSL)	Lake Area (acres)	Estimated Lake Volume (acre-ft)	Estimated Lake Volume (m^3/yr)	Estimate Lake Outflow Volume (acre-ft/yr)	Estimate Lake Outflow Volume (m^3/yr)	Estimated Hydraulic Residence Time (Years)
Dry Year (1988, 19 inches)	955.2	78.2	519	640,000	30.0	37,000	17.3
Average Year (1995, 27 inches)	956.0	84.4	584.9	721,000	298.4	368,000	2.0
Model Calibration Year (1997, 34 inches)	956.0	84.2	583.2	719,000	493.8	609,000	1.2
Wet Year (1983, 41 inches)	956.1	85.4	595.9	735,000	671.4	828,000	0.9

Lake Ann

Climatic Condition (Water Year, Inches of Precipitation)	Lake Elevation (MSL)	Lake Area (acres)	Estimated Lake Volume (acre-ft)	Estimated Lake Volume (m^3/yr)	Estimate Lake Outflow Volume (acre-ft/yr)	Estimate Lake Outflow Volume (m^3/yr)	Estimated Hydraulic Residence Time (Years)
Dry Year (1988, 19 inches)	955.0	114	1874.6	2,312,000	90.8	112,000	20.6
Average Year (1995, 27 inches)	955.8	116.6	1966.8	2,426,000	293.5	362,000	6.7
Model Calibration Year (1997, 34 inches)	955.8	116.7	1969.1	2,428,000	621.1	766,000	3.2
Wet Year (1983, 41 inches)	956.1	117.7	2004.3	2,472,000	807.6	996,000	2.5

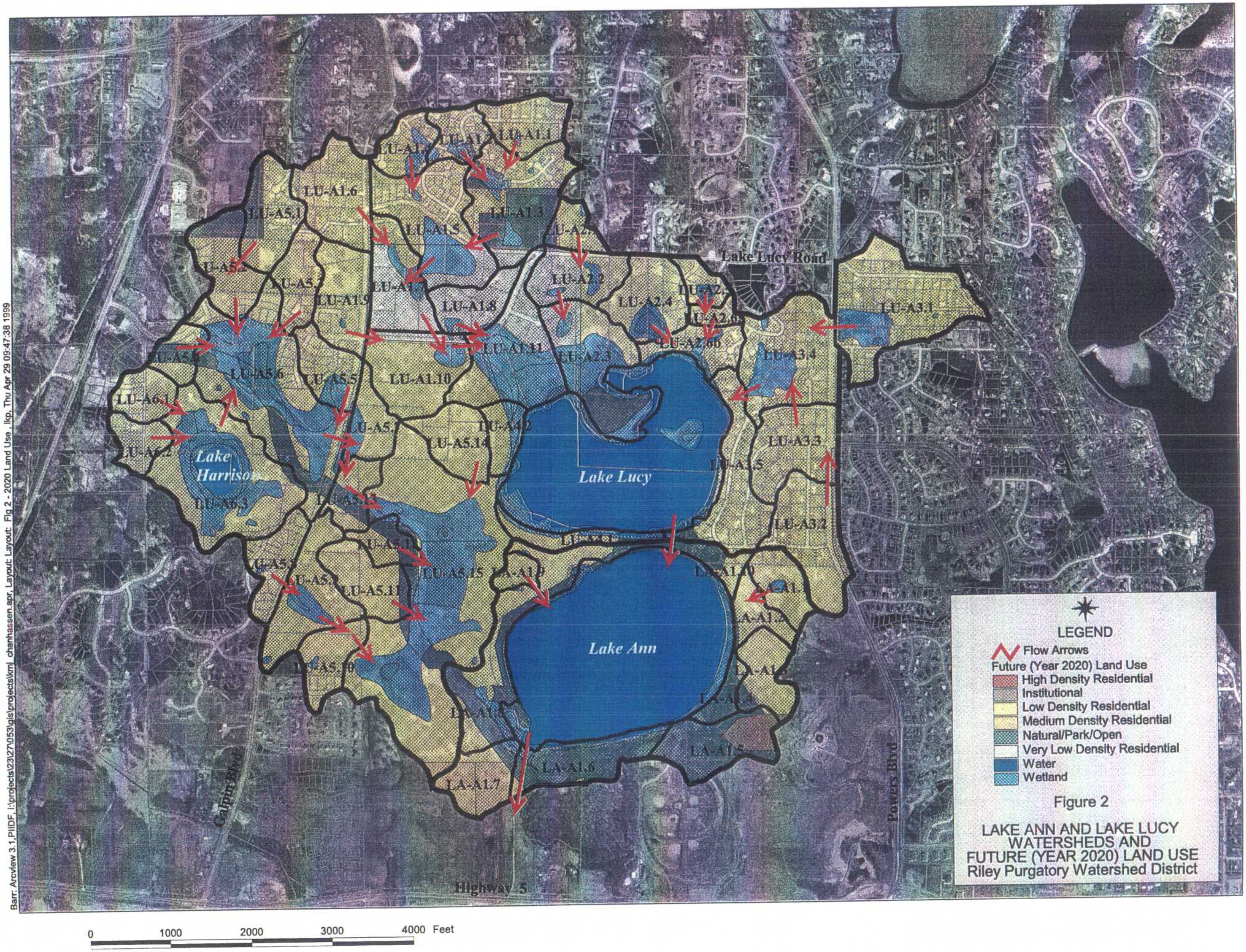

Figure 2

LAKE ANN AND LAKE LUCY WATERSHEDS AND FUTURE (YEAR 2020) LAND USE
Riley Purgatory Watershed District

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Of the twelve lakes in the watershed district, Lake Lucy is the sixth largest by surface area and by volume. Lake Lucy overflows to Lake Ann when its surface elevation exceeds 955.7 MSL (Mean Sea Level). Lake Ann is the fifth largest by surface area and the third largest by volume within the Riley-Purgatory-Bluff Creek Watershed District. Lake Ann overflows to form the headwaters of Riley Creek when its surface elevation exceeds 954.7 MSL.

Harrison Lake was also incorporated into this study. Under average hydrologic conditions, this lake is land-locked. Under flood conditions, however, this lake overflows into the Lake Lucy watershed system.

1.3 Water Quality

1.3.1 Data Collection

Water quality data were collected from Lake Lucy and Lake Ann from 1972 to 1997 (Barr, 1973a; Barr, 1973b; Barr, 1976; Barr, 1982; Barr, 1985, Barr, 1989, Barr, 1993, Barr, 1996a). The District has generally sampled lakes on a three-year rotating basis.

From September 1996 through October 1997, an intensive data collection program was completed to evaluate current water quality conditions and to calibrate the water quality models used in the use attainability analysis. The intensive data collection program involved more frequent lake sampling and the collection of samples at additional depths from lake surface to lake bottom than previous programs. Lake Ann was sampled more frequently than Lake Lucy (14 events versus 6) because of the higher water quality classification of Lake Ann (swimming versus fishing). Appendix A contains the data collected in this monitoring effort.

1.3.2 Baseline/Current Water Quality

1.3.2.1 Lake Lucy

The baseline water quality of Lake Lucy was determined by evaluating the average summer conditions (June to August) during the period from 1972 to 1985. Current water quality (1988-1997) were compared to the baseline averages (Table 4). In general, Lake Lucy water quality has not changed significantly between baseline and current conditions. Total phosphorus increased 4 percent from the baseline to the current period, suggesting that the lake is slightly more enriched in the current period than in the baseline period. The Secchi disc transparency decreased by 24 percent, as expected with greater total phosphorus inputs to the lake. However, chlorophyll *a* actually decreased 13 percent from the baseline to the current period. Normally, as total phosphorus increases, chlorophyll *a* increases and Secchi disc transparency (generally considered an

Table 4: A Comparison of Baseline Quality of Lake Lucy and Lake Ann with Current Conditions Based on Summer (June through August) Epilimnetic Averages

Lake Lucy

Chlorophyll a (mg/L)				Total Phosphorus (µg/L)				Secchi Disc (m)			
Baseline (1972-1985)		Current (1988-1997)		Baseline (1972-1985)		Current (1988-1997)		Baseline (1972-1985)		Current (1988-1997)	
Range:	15.0-40.5	Range:	21.3-27.8	Range:	48-83	Range:	54-79	Range:	1.3-2.2	Range:	1.0-1.4
Mean:	28.3	Mean:	24.6	Mean:	64	Mean:	67	Mean:	1.6	Mean:	1.2
1972:	40.5	1988:	27.8	1972:	83	1988:	79	1972:	1.5	1988:	1.0
1975:	26.5	1990:	21.3	1975:	48	1990:	76	1975:	1.7	1990:	1.4
1978:	15.0	1994:	21.7	1978:	56	1994:	59	1978:	1.4	1994:	1.1
1981:	22.4	1997:	27.8	1981:	64	1997:	54	1981:	1.3	1997:	1.3
1984:	32.6			1984:	82.5			1984:	2.3		
1985:	33.0			1985:	53			1985:	1.5		

Lake Ann

Chlorophyll a (mg/L)				Total Phosphorus (µg/L)				Secchi Disc (m)			
Baseline (1972-1985)		Current (1988-1997)		Baseline (1972-1985)		Current (1988-1997)		Baseline (1972-1985)		Current (1988-1997)	
Range:	3.8-13.0	Range:	5.7-13.0	Range:	25-44	Range:	22-27	Range:	1.6-2.8	Range:	1.8-3.2
Mean:	8.4	Mean:	8.7	Mean:	35	Mean:	24	Mean:	2.2	Mean:	2.4
1972:	13.0	1988:	13.0	1972:	38	1988:	23	1972:	2.0	1988:	2.6
1975:	11.4	1989:	8.6	1975:	31	1989:	25	1975:	1.8	1989:	2.2
1978:	6.0	1990:	10.5	1978:	30	1990:	22	1978:	1.6	1990:	1.9
1981:	8.2	1994:	5.8	1981:	41	1994:	25	1981:	2.0	1994:	1.8
1984:	3.8	1997:	5.7	1984:	44	1997:	27	1984:	2.8	1997:	3.2
1985:	7.8			1985:	25			1985:	2.8		

indicator of algal biomass) decreases. However, it is important to note that the average summer conditions in Lake Lucy vary greatly from year to year. In fact, none of the percent increases/decreases discussed above were found to be statistically significant to a 95 percent confidence interval.

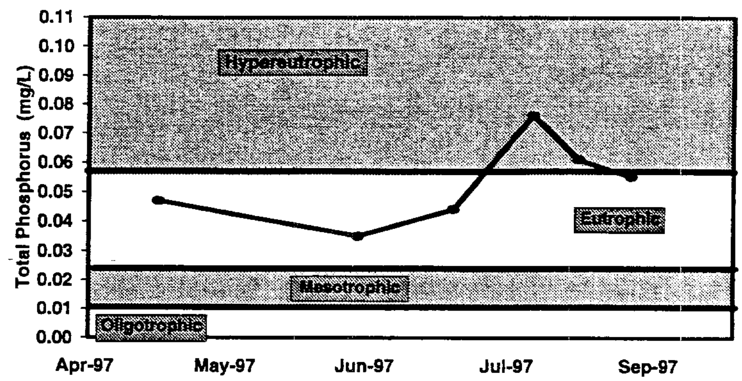
An evaluation of 1996 through 1997 Lake Lucy water quality data was completed to evaluate the state of the present water quality. The evaluation was based upon a standardized lake rating system. The rating system uses the lake's total phosphorus, chlorophyll *a*, and Secchi disc transparency measurements to assign the lake to a water quality category that best describes its water quality. Water quality categories include:

- Oligotrophic (i.e., excellent water quality)
- Mesotrophic (i.e., good water quality)
- Eutrophic (poor water quality)
- Hypereutrophic (very poor water quality).

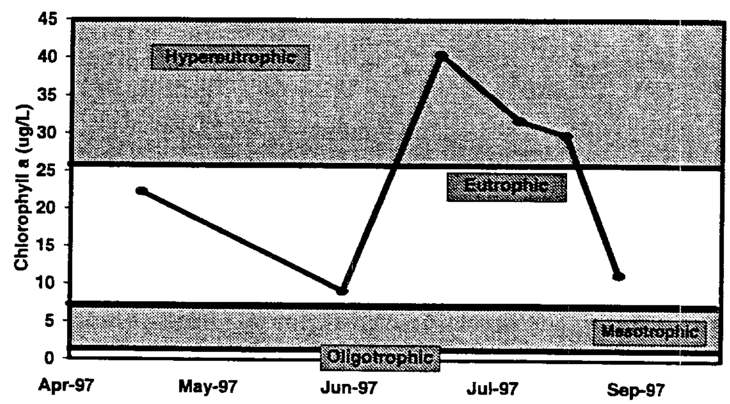
Total phosphorus, chlorophyll *a*, and Secchi disc transparency were used as the key water quality indicators to determine the lake's current water quality for the following reasons. Phosphorus generally controls the growth of algae in lake systems. Of all the substances needed for biological growth, phosphorus is generally the one present in limited quantity. Consequently, when phosphorus is added to a system, it enhances algal growth. Chlorophyll *a* is the main pigment in algae; therefore, the concentration of chlorophyll *a* in the water indicates the amount of algae present in the lake. Secchi disc transparency is a measure of water clarity, and is inversely related to algal abundance. Water clarity determines recreational use impairment. Figure 3a summarizes the seasonal changes in summer concentrations of total phosphorus and chlorophyll *a*, and Secchi disc transparencies for Lake Lucy during 1996 through 1997. The data are compared with a standardized lake rating system.

Total phosphorus data collected from Lake Lucy during 1997 were within the eutrophic category during spring through mid-summer and were within the hypereutrophic category during the late-summer period. Because phosphorus has been shown to most often limit the growth of algae, the phosphorus-rich lake waters indicate the lake has the potential for abundant algal growth throughout the summer period. Algal growth is a concern because abundant algal growth degrades the lake's water quality and interferes with the use of the lake for recreational activities, including fishing. The 1997 Lake Lucy average summer total phosphorus concentration (measured at 0- to 2-meter depth) was 0.054 mg/L. This concentration indicates the lake experiences frequent nuisance algal blooms. As phosphorus concentrations increase from 0.030 mg/L to

Lake Lucy: Epilimnetic (0-2 Meters) Total Phosphorus Concentration



Lake Lucy: 1996-1997 Epilimnetic Chlorophyll Concentrations



Lake Lucy: 1996-1997 Secchi Disc Transparencies

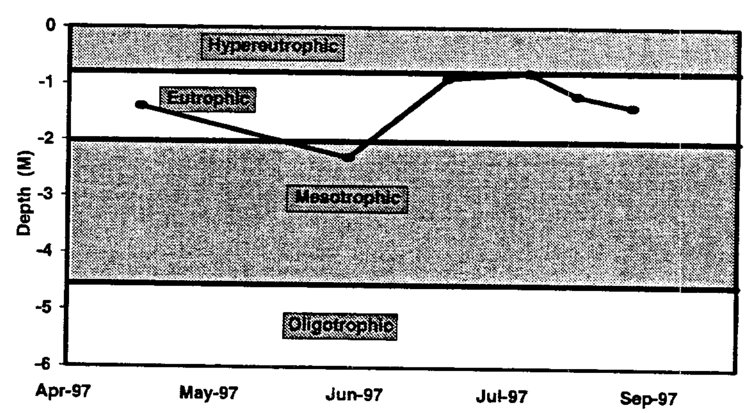


Figure 3a:
Seasonal Changes in Concentrations of Total Phosphorus and Chlorophyll a and Secchi Disc Transparencies in Lake Lucy

0.060 mg/L, the frequency of nuisance algal blooms (greater than 0.020 mg/L chlorophyll *a*) generally increases from 5 percent of the summer to about 70 percent of the summer (Heiskary and Wilson, 1990).

Chlorophyll *a* measurements (measured at 0 to 2 meter depth) from Lake Lucy during 1997 were in the eutrophic category during the early-summer and were in the hypereutrophic categories during the remaining portion of the summer. The data indicate nuisance algal blooms (greater than 20 μg/L chlorophyll *a*) occurred throughout July and August.

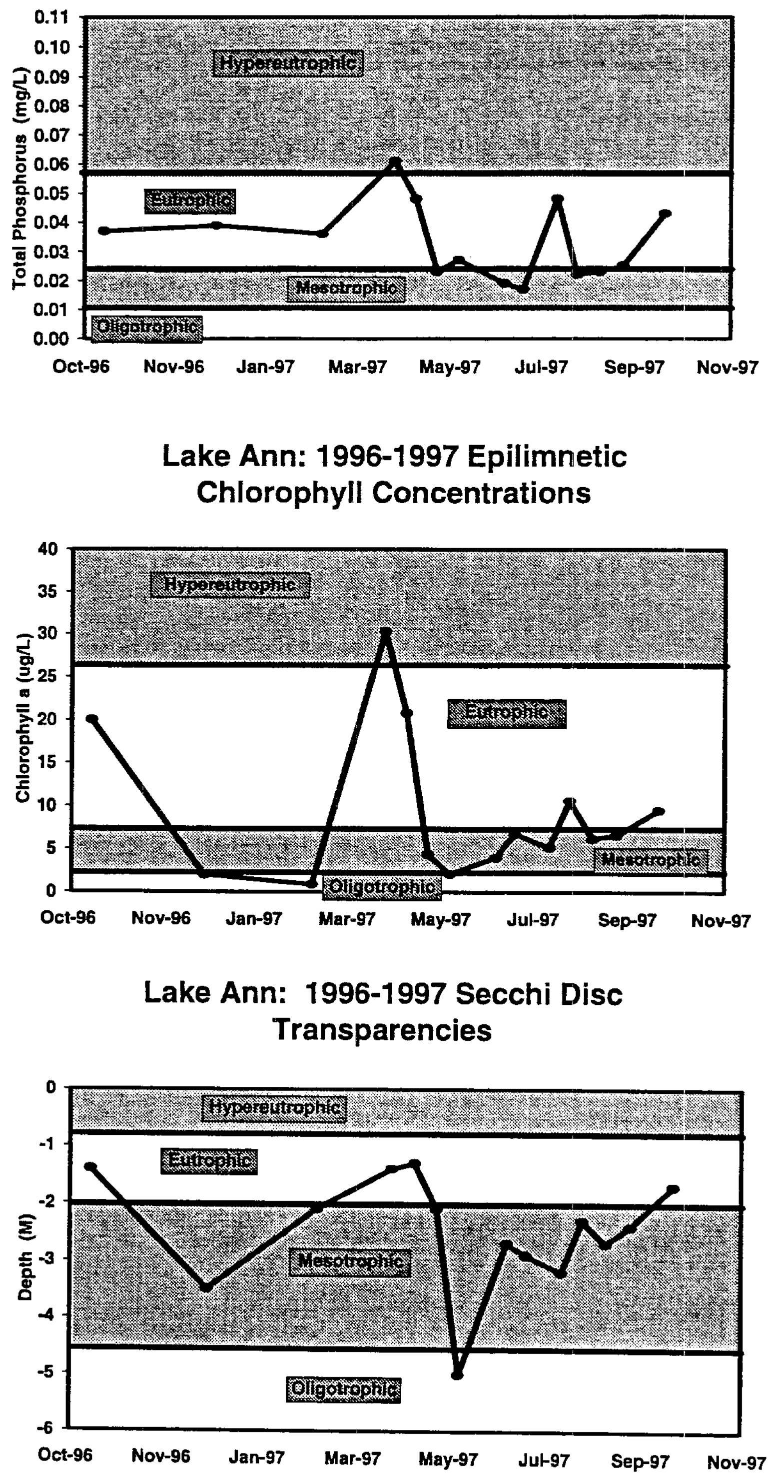
The 1997 Secchi disc measurements in Lake Lucy were in the eutrophic/mesotrophic category during the early summer and were in the eutrophic category during the remainder of the summer. The data indicate the lake's water transparency is influenced by algal abundance. Lake Lucy Secchi disc measurements during the 1997 summer period ranged from 0.8 to 2.3 meters.

1.3.2.2 Lake Ann

The baseline water quality of Lake Ann was also determined by evaluating the average summer conditions (June to August) during the period from 1972 to 1985. Current water quality data (1988-1997) were compared to the baseline averages (Table 4). Like Lake Lucy, Lake Ann water quality has not changed significantly between baseline and current conditions. However, total phosphorus has decreased 30 percent from the baseline to the current period, suggesting that the lake water quality is improving. The Secchi disc transparency increased by 9 percent, as expected with lesser total phosphorus inputs to the lake. However, chlorophyll *a* increased by 5 percent from the baseline to the current period. Again, it is important to note that the average summer conditions in Lake Ann vary greatly from year to year and that none of the percent increases/decreases discussed above were found to be statistically significant to a 95 percent confidence interval.

Figure 3b summarizes the seasonal changes in summer concentrations of total phosphorus and chlorophyll *a* and Secchi disc transparencies for Lake Ann during 1996 through 1997. Total phosphorus data collected from Lake Ann during 1996 through 1997 were generally within the eutrophic category during fall through spring and the mesotrophic category during the remainder of the period except for two sampling events—one in July 1997 and one in October 1997. The data indicate the lake's water quality fluctuates throughout the summer but has the potential for being poor when the lake's use for swimming and other recreational uses is highest. Because phosphorus has been shown to most often limit the growth of algae, the phosphorus-rich lake waters indicate the lake has the potential for abundant algal growth throughout a portion of the summer period. Algal growth degrades the lake's water quality and interferes with the use of the lake for swimming

Lake Ann: Epilimnetic (0-2 Meters) Total Phosphorus Concentration



Lake Ann: 1996-1997 Epilimnetic Chlorophyll Concentrations

Lake Ann: 1996-1997 Secchi Disc Transparencies

Figure 3b:
Seasonal Changes in Concentrations of Total Phosphorus and Chlorophyll a and Secchi Disc Transparencies in Lake Ann

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and other recreational activities. The 1997 Lake Ann average summer total phosphorus concentration (measured at 0- to 2-meter depth) was 0.027 mg/L. Although this average is close to the mesotrophic category (0.010 to 0.025 mg/L), total phosphorus reached a maximum of 0.048 mg/L in early August. A total phosphorus concentration of 0.060 mg/L is considered the upper limit for a lake to be considered swimmable (MPCA, 1997) and indicates the lake may experience nuisance algal blooms in late-summer.

The 1997 Lake Ann chlorophyll *a* measurements (measured at 0 to 2 meters) were highest in late fall and spring when the lake was turning over. Measurements were generally in the mesotrophic (good water quality) category during most of the summer, except for August, when chlorophyll *a* reached eutrophic levels (>7.5 µg/L chlorophyll *a*). No chlorophyll *a* measurements exceeded nuisance levels (>20 µg/L) during the summer. Therefore, the high phosphorus observed in August did not appear to create extremely high algal blooms.

The 1997 Secchi disc measurements in Lake Ann were in the mesotrophic (good water quality) for most of the year, except for the fall and spring when the lake was turning over. Lake Ann Secchi disc measurements during the 1997 summer period ranged from 2.3 to 5.0 meters. The data indicate that Lake Ann has minimal recreational-use impairment during the summer.

1.4 Ecosystem Data

1.4.1 Aquatic Ecosystems

The use attainability analysis included an evaluation of Lake Lucy and Lake Ann ecosystem data. Ecosystem describes the community of living things and their interaction with the environment in which they live with each other. The interdependency of the ecosystem is best illustrated by the food chain (See Figure 4). The food chain begins with the primary producers, which are green plants, such as phytoplankton (algae) and macrophytes (aquatic weeds). They take in carbon dioxide and water and use the sun's energy to produce their own food. Next in the chain are the primary consumers or herbivores, which eat plants. The most populous of these consumers are the zooplankton, which prey upon algae (phytoplankton). Succeeding the primary consumers are the secondary consumers or planktivores, which include bluegill sunfish and crappies. The diet of these fish includes zooplankton and other primary consumers. Tertiary consumers or predator fish occupy the next level of the food chain. This group includes bass and northern pike, which consume bluegill sunfish and crappies. At the top of the food chain are omnivores, such as humans, which eat bass and northern pike. A less visible component of the food chain, the decomposers, include bacteria living at the lake bottom, which break down dead and decaying organisms into nutrients and other essential elements. All

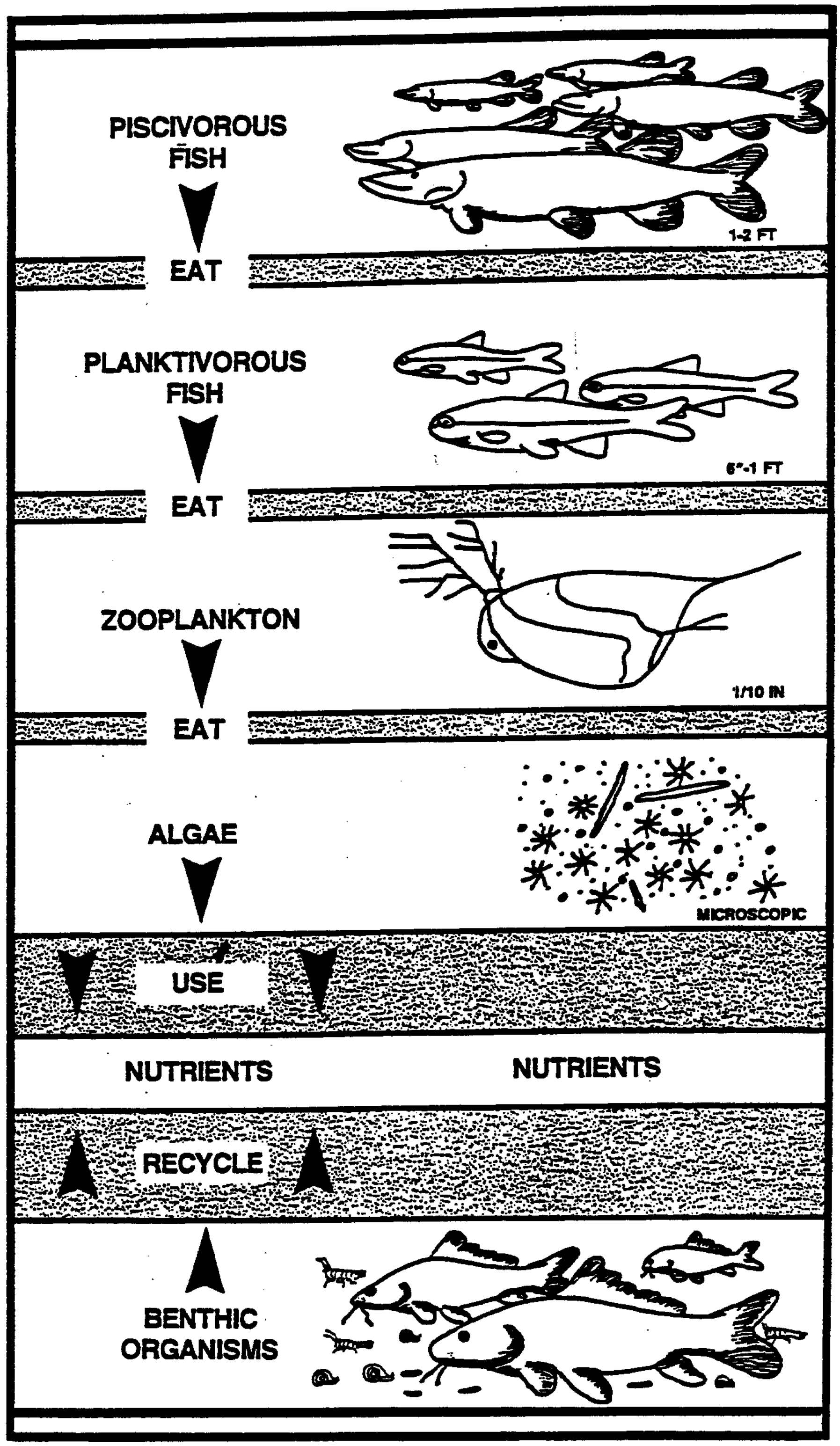


Figure 4
THE FOOD WEB

life in a food chain is interdependent. If any one group becomes unbalanced, all life in the food chain is adversely impacted. An aquatic ecosystem is managed to maintain balance between the phytoplankton, zooplankton, small fish (bluegill sunfish and crappies), and large fish (bass and northern pike).

The Lake Lucy ecosystem is typical for a eutrophic, temperate lake in this region. The Lake Ann ecosystem is typical for a mesotrophic, temperate lake in this region.

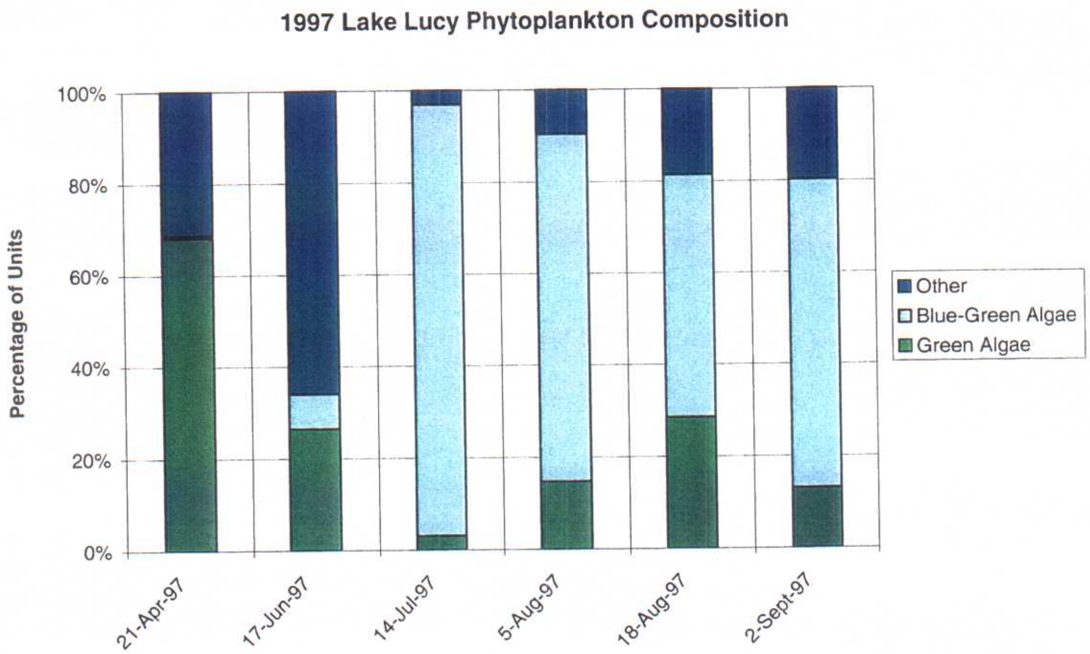
1.4.2 Phytoplankton

The phytoplankton species in Lake Lucy and Lake Ann form the base of the lake's food web and directly impact the lake's fish production. Phytoplankton, also called algae, are small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish. A phytoplankton population in balance with the lake's zooplankton population is ideal for fish production. An inadequate phytoplankton population reduces the lake's zooplankton population and adversely impacts the lake's fishery. Excess phytoplankton, however, reduce water clarity, and reduced water clarity can interfere with the recreational usage of a lake. Survey results for 1997 are presented in Appendix B.

As in previous years, blue-green and green algae were generally the dominant types of phytoplankton observed in 1997 (Figure 5). Blue-green algae were especially dominant in Lake Lucy. Green algae are edible to zooplankton and serve as a valuable food source. Blue-green algae are considered a nuisance type of algae because they:

- are generally inedible to fish, waterfowl, and most zooplankters;
- float at the lake surface in expansive algal blooms;
- may be toxic to animals when occurring in large blooms;
- can disrupt lake recreation because they are most likely to be present during the summer months.

Blue-green and green algal growth is stimulated by excess phosphorus loads. The growing conditions during July and August are particularly favorable to blue-greens, and they have a competitive advantage over the other algal species during this time.



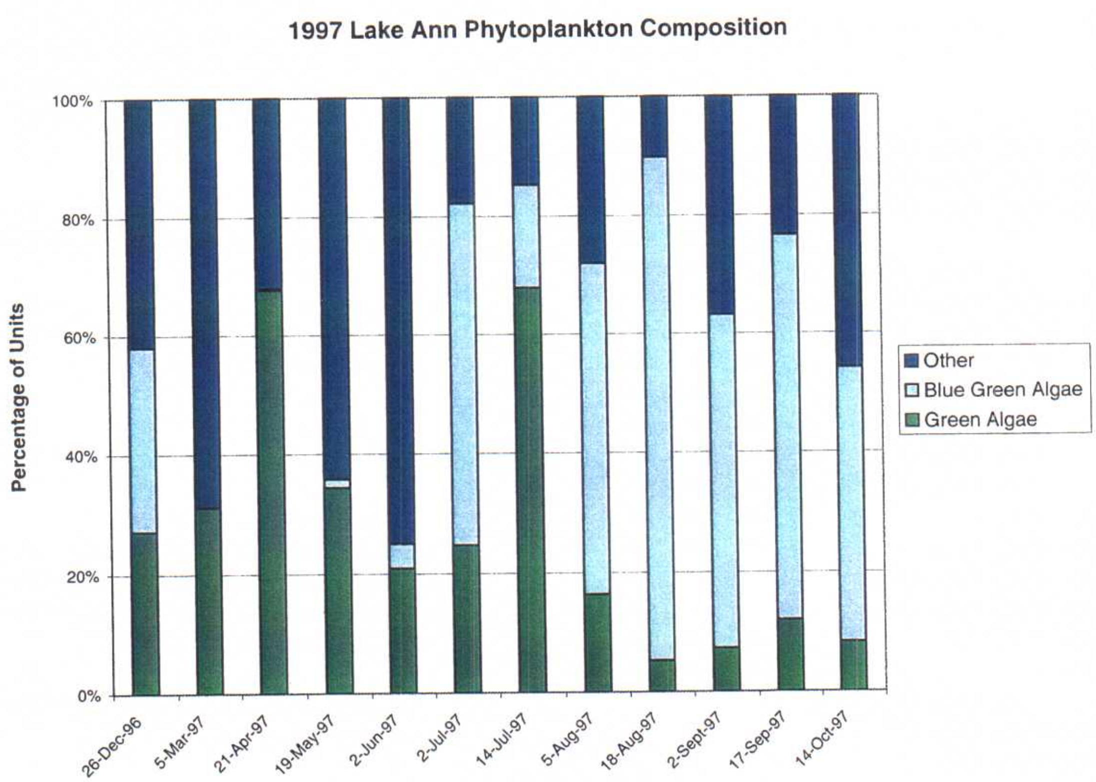


Figure 5: 1997 Phytoplankton Composition in Lake Lucy and Lake Ann

1.4.3 Zooplankton

Zooplankton are the second step in the Lake Lucy and Lake Ann food webs and are considered vital to its fishery. They are microscopic animals that feed on particulate matter, including algae, and are, in turn, eaten by fish. Protection or enhancement of the lake's zooplankton community through judicious management practices affords protection to the lake's fishery.

The 1997 Lake Lucy and Lake Ann zooplankton abundance was slightly lower than those observed in earlier sampling events. However, the zooplankton abundance in both lakes vary greatly from year to year (see Figure 6). The rotifers and copepods in Lake Lucy and Lake Ann graze primarily on extremely small particles of plant matter and do not significantly affect the lake's water quality. However, the cladocera graze primarily on algae and can improve water quality if present in abundance. Survey results for 1997 are presented in Appendix B.

1.4.4 Macrophytes

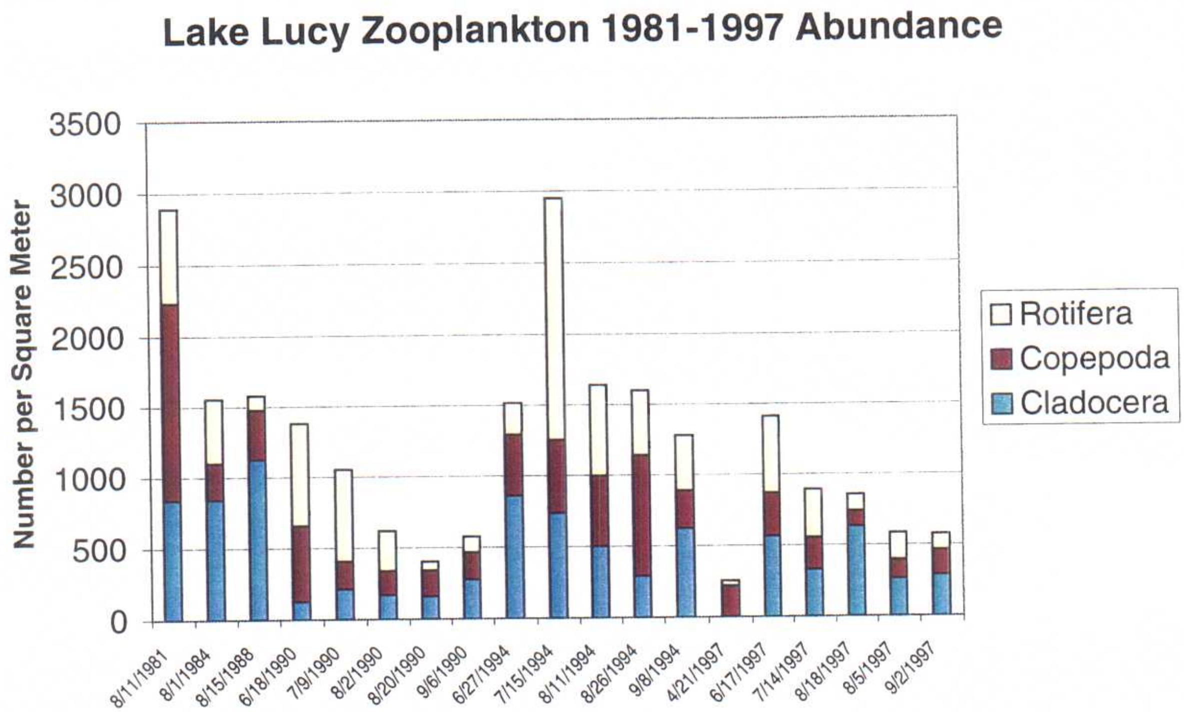
Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. Typical functions of a lake's macrophyte community include the following:

- Provide habitat for fish, insects, and small invertebrates
- Provide food for waterfowl, fish, and wildlife
- Produce oxygen
- Provide spawning areas for fish in early spring/provide cover for early life stages of fish
- Help stabilize marshy borders and protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Surveys of the aquatic plant community in Lake Lucy and Lake Ann were completed by the District during June and August of 1994 and 1997. Survey results are presented in Appendix B.

1.4.4.1 Lake Lucy

During 1994, macrophytes were identified to a relative depth of 10 feet. In some areas, the submerged plants were dominated by a dense growth of coontail (*Ceratophyllum demersum*, a native species) in June and August. Northern watermilfoil (*Myriophyllum sibericum*) was a prevalent species in June, but died back later in the summer. Northern watermilfoil, a species native to this region, is often confused with the related



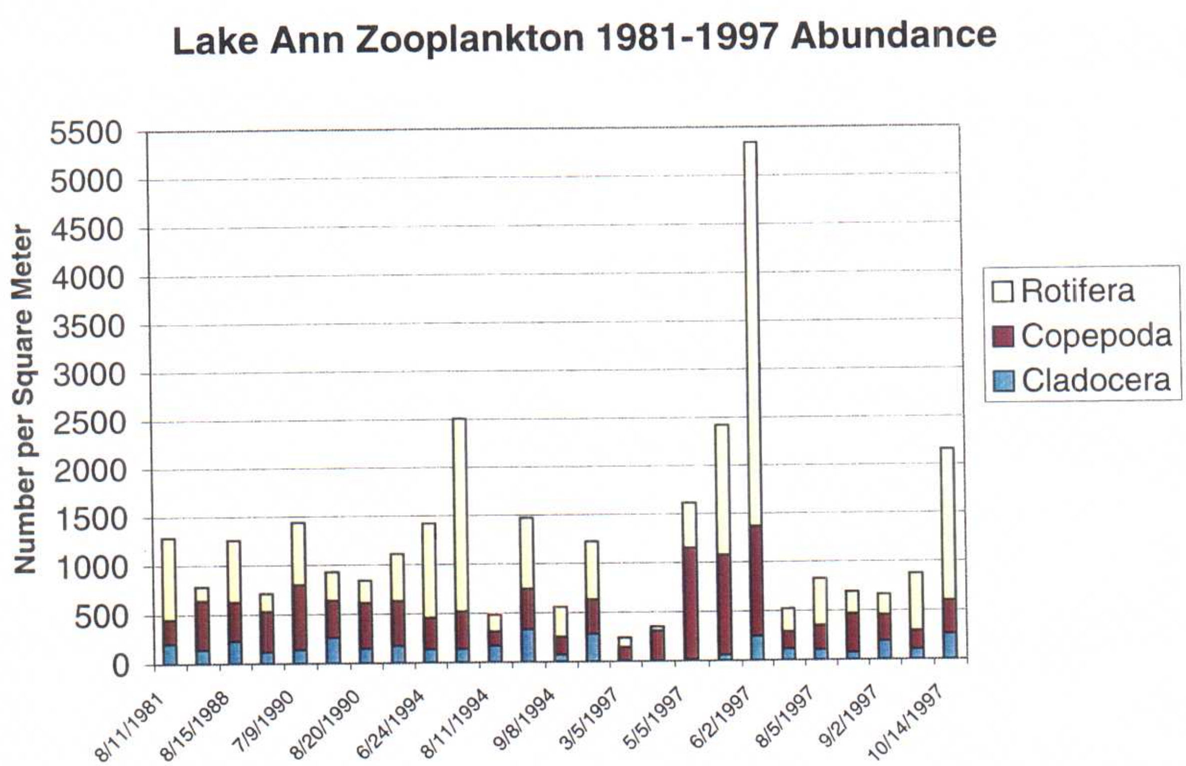


Figure 6: Lake Lucy and Lake Ann Zooplankton Abundance 1982-1997

undesirable non-native Eurasian watermilfoil. Northern watermilfoil is a desirable species that provides beneficial habitat for the lake's fishery.

During 1997, macrophytes were once again identified to a maximum depth of 10 feet. In some areas, the submerged plants were dominated by a dense growth of curly-leaf pondweed *(Potamogeton crispus)* in June. Curly-leaf pondweed is an undesirable non-native species. It frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. A dense growth also creates a refuge for small fish, making it difficult for larger fish, such as bass, to find and capture the small fish they need for food. Other areas, however, were dominated by coontail, as in 1994. Northern watermilfoil was less prevalent in Lake Lucy during 1997. In general, Lake Lucy continued to have a diverse macrophyte community in 1997.

1.4.4.2 Lake Ann

During 1994, macrophytes were identified to a maximum depth of 9 feet. Lake Ann had a very diverse macrophyte community, with only two areas, on the west and east sides of the lake, that had predominant growths of curly-leaf pondweed. These growths died off by late-summer and were replaced by diverse growths of more desirable native species.

During 1997, macrophytes were identified to a maximum depth of 10 feet and were even more diverse than during the 1994 surveys. In fact, Lake Ann hosted an excellent array of plant species during both June and August of 1997.

1.5 Water-Based Recreation

Lake Lucy is used primarily for fishing. There is currently no fishing pier or public access to the lake, However, in summer 1998, many anglers parked at Lake Ann and walked back into Lake Lucy in order to fish for large bluegills and largemouth bass (Ellison, 1999).

Lake Ann is used for all types of recreational activities, including swimming. The municipal swimming and boat access in Lake Ann Park located along the southeast shore is owned and maintained by the city of Chanhassen. Lake Ann is considered an excellent northern pike fishery, despite its small size and proximity to a metropolitan area.

1.6 Fish and Wildlife Habitat

1.6.1 Lake Lucy

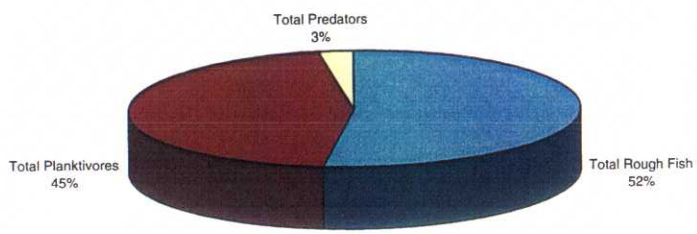
During 1992, the MDNR classified Lake Lucy and other Minnesota lakes relative to fisheries. This ecological classification is a function of lake area, percentage of the lake surface area that is littoral, maximum depth, degree of shoreline development, Secchi disc transparency and total alkalinity. According to its ecological classification, Lake Lucy is a Class 42 lake, which signifies a lake that may be better suited for wildlife than for fish (Schupp, 1992). The average Secchi disc transparency for this ecological class is 0.9 m (Schupp, 1992). In 1997, Lake Lucy's average summer Secchi disc transparency was 1.3 m. Therefore, Lake Lucy's current conditions indicate that its water quality is better than the average lake in its ecological class.

Lake Lucy's most abundant fish species in 1995 were black bullheads, bluegills, pumpkinseed and hybrid sunfish, largemouth bass, black crappies and northern pike (according to the MDNR's most recent fisheries survey). Black bullhead abundance was higher than average for a lake with an ecological classification of 42. However, the weight of the bullheads was considerably lower than average. Bluegills and other sunfish (planktivores) were also present in higher than average numbers but with an average weight. The remaining sport fish (predators) numbers and weights were comparable to the lake class average. Figure 7 shows the proportions of fish (in terms of predators, planktivores and rough fish) in the 1995 MDNR fisheries survey. The lack of public access on Lake Lucy prevents the MDNR from stocking.

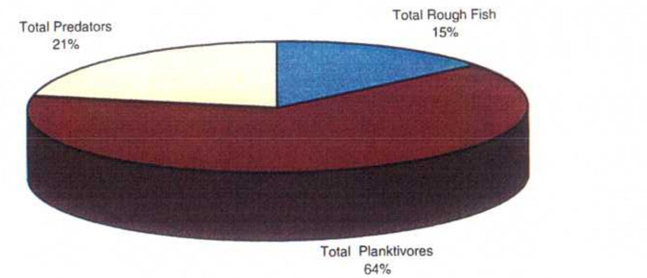
Threats to the lake's fishery habitat include oxygen depletion leading to winter fish kills. The most recent harsh winterkill was in 1994 according to the MDNR. Similar occurrences could be expected every 10 to 20 years, under current lake water quality conditions. However, if the lake water quality is degraded, the lake could experience more frequent winterkills. Species that are especially sensitive to low oxygen conditions are bluegills, sunfish and largemouth bass. More tolerant species include bullheads, northern pike and crappies.

Lake Lucy provides habitat for seasonal waterfowl, such as ducks and geese, through diverse macrophyte communities in a large littoral zone.

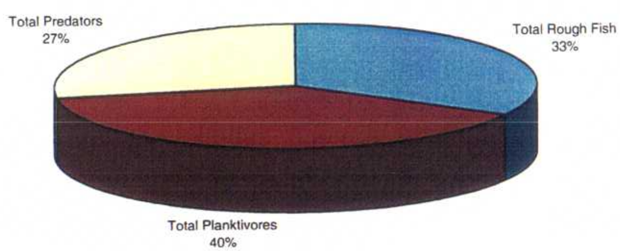
Lake Lucy 1995
Gillnet and Trapnet Catch Composition (By Abundance)



Lake Ann 1995
Gillnet and Trapnet Catch Composition (By Abundance)



Lake Lucy 1995
Gillnet and Trapnet Catch Composition (By Weight)



Lake Ann 1995
Gillnet and Trapnet Catch Composition (By Weight)

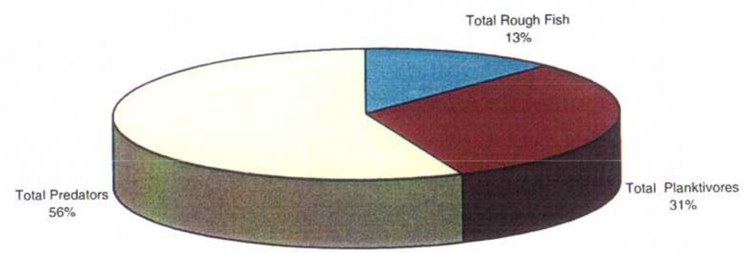


Figure 7: Lake Lucy and Lake Ann 1995 Fisheries Survey Results: Total Predators, Planktivores and Rough Fish by Abundance and Weight

1.6.2 Lake Ann

According to its ecological classification, Lake Ann is a Class 24 lake, which signifies a good, permanent fish lake (Schupp, 1992). The average Secchi disc transparency for this ecological class is 1.3 m (Schupp, 1992). In 1997, Lake Ann's average summer Secchi disc transparency was 3.2 m. Therefore, Lake Ann's current conditions indicate that its water quality is considerably better than the average lake in its ecological class.

Lake Ann's most abundant fish species in 1995 were northern pike, yellow perch, bluegills and black crappies (according to the MDNR's most recent fisheries survey). Only one largemouth bass was caught in the gillnet and trapnet sets. However, this low catch is attributed to the poor recruitment of bass to these capture methods. Northern pike abundance and weight was slightly higher than average for a lake with an ecological classification of 24. Yellow perch abundance was higher than the lake class average with average weight. Bluegills were also present in higher than average numbers and weights, but the distribution of ages led fisheries managers to report that the bluegills are exhibiting poor growth. Black crappies were present within normal levels Lake Ann fisheries data is also shown in Figure 7.

Lake Ann provides habitat for seasonal waterfowl such as ducks and geese through diverse macrophyte communities, though it has a much smaller littoral zone than Lake Lucy.

1.7 Discharges

1.7.1 Natural Conveyance Systems

The natural inflow to Lake Lucy is stormwater runoff from its direct watershed, both over land (subwatersheds: LU-A3.5, LU-A4.1 and LU-A4.2) and through wetland systems (LU-A1.11, LU-A2.3, LU-A2.6b and LU-A5.15) (Figure 2). There are no streams or rivers that convey flow to Lake Lucy. In many cases, stormwater conveyance systems in the upland areas discharge into the wetland systems described above, creating an interconnected network of natural and constructed flow paths. For this reason the natural and constructed stormwater conveyance systems will be discussed together in the subsequent sections of this report under the heading of "Stormwater Conveyance Systems."

The natural inflow to Lake Ann is comprised largely of outflow from Lake Lucy. The remaining inflow is stormwater runoff from Lake Ann's direct watershed. Lake Ann's natural stormwater conveyances will also be discussed in the "Stormwater Conveyance Systems" sections of this report.

1.7.2 Stormwater Conveyance Systems

The Lake Lucy stormwater conveyance systems are comprised of a network of storm sewers and wet detention ponds (both natural wetlands and constructed ponds) within the watershed tributary to the lake. The wet detention ponds provide water quality treatment of stormwater runoff. These wet detention ponds are comprised of five wet detention basins and 15 upland wetlands (Table 5, Figure 8). The Lake Ann stormwater conveyance system is comprised mostly of overland flow from its direct watershed. There is only one wetland in the Lake Ann watershed that has enough wet detention to affect stormwater treatment (Table 5). Dimensions and outlet structures for each of the existing wetlands was taken from the *City of Chanhassen Surface Water Management Plan* (1994) and verified in the field. Information on the constructed detention basins was obtained from development plans provided to Barr Engineering by developers in the Riley-Purgatory-Bluff Creek Watershed District as part of the permitting process. This information was also verified in the field.

Wet detention ponds consist of a permanent pool of water and have the capacity to hold runoff and release it at lower rates than incoming flows. Wet detention ponds are used to interrupt the transport phase of sediment and pollutants associated with it, such as trace metals, hydrocarbons, nutrients, and pesticides. Consequently, wet detention ponds are one of the most effective methods available for treatment of nutrient-rich runoff.

During a storm event, polluted-runoff enters the detention basin and displaces "clean" water until the plume of polluted runoff reaches the basin's outlet structure. When the polluted-runoff reaches the basin outlet, it has been diluted by the water previously held in the basin. This dilution further reduces the pollutant concentration of the outflow. In addition, the coarse sediments being transported by the polluted-runoff and the pollutants associated with these sediments are trapped in the detention basin.

As storm flows subside, finer sediments suspended in the basin's pool will have a relatively longer period of time to settle out. These finer sediments eventually trapped in the basin's permanent pool will continue to settle until the next storm flow occurs. In addition to efficient settling, this long detention time allows some removal of dissolved nutrients through biological activity (Walker, 1987). Dissolved nutrients are mainly removed by algae and aquatic plants. After the algae die, the dead algae can settle to the bottom of the pond, carrying with them the dissolved nutrients that were consumed, to become part of the bottom sediments.

Table 5: Existing Constructed Ponds and Wetlands that Function as Treatment Ponds in the Lake Lucy and Lake Ann Watersheds

Lake Lucy

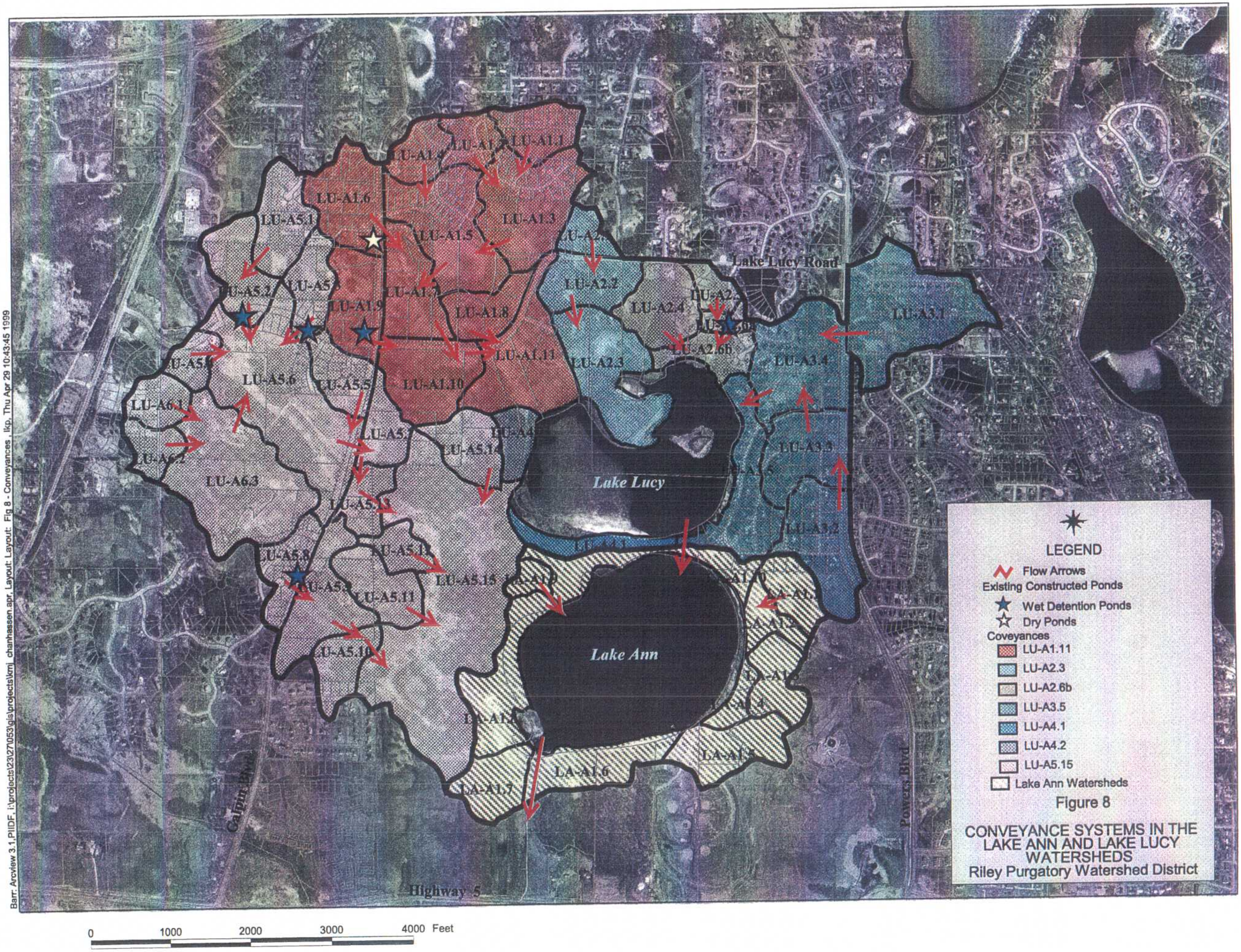
Constructed Pond in Subwatershed:	Dead Storage Surface Area (acres)	Dead Storage Volume (acre-ft)	Dead Storage Average Depth (ft)	Live Storage Surface Area (acres)	Live Storage Volume (acre-ft)	Outlet Structure
LU-A1.9	0.5	2	4	1.2	5.8	12" pipe
LU-A2.6a	0.1	0.2	2	0.3	0.8	21" pipe
LU-A5.2	0.1	0.2	2	0.2	0.5	15" pipe
LU-A5.3	0.3	1.2	4	0.5	0.8	18" pipe
LU-A5.8	0.3	0.6	2	0.4	0.8	12" pipe
LU-A1.6	--	0	0	0.5	1.2	16" pipe

Wetland in Subwatershed:	Classification* (from City of Chanhassen SWMP)	Dead Storage Surface Area (acres)	Dead Storage Volume (acre-ft)	Dead Storage Average Depth (ft)	Live Storage Surface Area (acres)	Live Storage Volume (acre-ft)	Outlet Structure
LU-A1.1	Natural	0.3	0.1	0.4	1.3	1.6	12" pipe
LU-A1.2	Agricultural/Urban	0.4	1.1	3.1	0.6	1.2	12" pipe
LU-A1.3	Agricultural/Urban	2.3	4.6	2.0	3.4	6.1	15" pipe
LU-A1.4	Agricultural/Urban	0.9	2.4	2.7	1.2	1.9	12" pipe
LU-A1.5	Agricultural/Urban	1.4	2.8	2.0	4.0	10.2	15" pipe
LU-A1.8	Agricultural/Urban	0.9	2.4	2.7	1.1	1.9	12" pipe
LU-A2.2	Agricultural/Urban	4.1	12.3	3.0	4.6	3.9	Overland Channel
LU-A2.4	Natural	2.7	8.1	3.0	3.7	3.5	Overland Channel
LU-A2.5	Natural	0.8	1.5	2.0	0.9	0.8	Overland Channel
LU-A3.1	Agricultural/Urban	1.6	3.2	2.0	0.0	0.0	16" pipe
LU-A3.4	Agricultural/Urban	--	0.0	0.0	5.6	9.8	30" pipe
LU-A5.5	Agricultural/Urban	1.6	3.1	2.0	1.7	1.5	Overland Channel
LU-A5.6	Natural	0.6	1.5	2.5	10.6	17.5	24" pipe
LU-A5.15	Natural	21.2	17.4	0.8	40.0	49.0	Overland Channel
LU-A6.3	Natural	22.2	121.5	5.5	25.0	23.8	Overland Channel

Lake Ann

Wetland in Subwatershed:	Classification* (from City of Chanhassen SWMP)	Dead Storage Surface Area (acres)	Dead Storage Volume (acre-ft)	Dead Storage Average Depth (ft)	Live Storage Surface Area (acres)	Live Storage Volume (acre-ft)	Outlet Structure
LA-A1.1	Agricultural/Urban	1.7	1.4	0.8	2.6	2.6	Overland Channel

* Natural wetlands are defined in Chanhassen's Surface Water Management Plan as wetlands that are still in their natural state and typically show little sign of impact from surrounding land usage. Agricultural/Urban wetlands are defined as wetlands that have been influenced by agricultural or urban (residential, commerical or industrial) land usage.


LEGEND
Flow Arrows
Existing Constructed Ponds
Wet Detention Ponds
Dry Ponds
Coveyances
LU-A1.11
LU-A2.3
LU-A2.6b
LU-A3.5
LU-A4.1
LU-A4.2
LU-A5.15
Lake Ann Watersheds
Figure 8
CONVEYANCE SYSTEMS IN THE LAKE ANN AND LAKE LUCY WATERSHEDS
Riley Purgatory Watershed District
Lake Lucy
Lake Ann
Lake Lucy Road
Highway 5
Powers Blvd
Galpin Blvd
LU-A1.6
LU-A1.3
LU-A1.5
LU-A1.8
LU-A1.9
LU-A1.10
LU-A1.11
LU-A2.2
LU-A2.3
LU-A2.4
LU-A2.6b
LU-A3.1
LU-A3.2
LU-A3.3
LU-A3.4
LU-A5.1
LU-A5.2
LU-A5.5
LU-A5.6
LU-A5.8
LU-A5.10
LU-A5.11
LU-A5.14
LU-A5.15
LU-A6.1
LU-A6.3
LA-A1.6
LA-A1.7
0 1000 2000 3000 4000 Feet
Barr: Arcview 3.1,PIIDF, i:\projects\23\27\053\gis\projects\kmj_chanhassen.apr, Layout: Layout: Fig 8 - Conveyances , lkp, Thu Apr 29 10:43:45 1999

The wet detention process results in good pollutant removal from small storm events. Runoff from larger storms will experience pollutant removal, but with lower efficiency levels. Studies have shown that because of the high frequency distribution of small storm events, wet detention ponds can be very important to long-term pollutant removal.

Stormwater is conveyed to Lake Lucy via seven stormwater conveyance systems. For the purposes of this report, stormwater conveyance systems are defined as a system of watersheds, storm sewers, detention ponds and wetlands that all drain to the lake through the same terminating watershed. Each conveyance system will be named after the terminating watershed in each network (LU-A1.11, LU-A2.6b, LU-A3.5, LU-A4.1, LU-A4.2, LU-A5.15). These stormwater conveyance systems are shown on Figure 8.

Because the stormwater runoff in the Lake Ann watershed comes only from the lake's direct watershed, and because each contributing subwatershed is so small, all of Lake Ann's runoff information will be presented together as one stormwater conveyance system (Figure 8), named "LA-A1.1 Through LA-A1.10."

1.7.3 Public Ditch Systems

There are no public ditch systems that affect Lake Lucy or Lake Ann.

1.8 Appropriations

There are no known water appropriations from Lake Lucy or Lake Ann.

2.0 Assessment of Lake Lucy and Lake Ann Problems

2.1 Appropriations

There are no known water appropriations from Lake Lucy or Lake Ann.

2.2 Discharges

The current water quality in Lake Lucy and Lake Ann is considered acceptable. However, the water quality in these lakes is greatly affected by the amount of phosphorus loading they receive. As development continues in these watersheds, phosphorus loads can be expected to increase, worsening water quality in both Lake Lucy and Lake Ann.

A detailed analysis of current and future discharges was completed to determine phosphorus sources and management opportunities to reduce the amount of phosphorus added to the lake. Because phosphorus typically moves either in water as soluble phosphorus dissolved in the water or attached to sediments carried by water, the determination of the volume of water discharged to Lake Lucy and Lake Ann annually was an important step in defining the amount of phosphorus discharged to the lake. During development of the Plan, literature export rate coefficients were used to estimate the annual water and phosphorus loads to the lake. The Plan recommended using the water quality model XP-SWMM, the EPA's Stormwater and Wastewater Management Model (with a graphical interface by XP Software), in the final use attainability analysis to provide a more precise estimate of water and phosphorus loads. However, because the P8 model (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds; IEP, Inc., 1990) provides more accurate predictions of phosphorus loads to a lake than XP-SWMM, P8 was selected instead. The phosphorus and water loads estimated with P8 for the 1996-1997 water year were entered into an in-lake mass balance model so that lake phosphorus concentration could be estimated. These 1997 concentrations were compared to 1996-1997 monitoring data to ensure that the model was producing reasonable results. The calibrated model was then used to estimate discharges under varying climatic conditions and best-management practice options. The methods employed to create and calibrate the P8 and in-lake models are described in detail in Appendices C and D. Details of phosphorus discharges to Lake Lucy and Lake Ann and management opportunities follow.

2.2.1 Natural Conveyance Systems

The natural conveyance systems in the Lake Lucy and Lake Ann watersheds are discussed in conjunction with the stormwater conveyance systems in the following section.

2.2.2 Stormwater Conveyance Systems

During the 1996-1997 water year (September 1996 to October 1997), Lake Lucy received an estimated 153 lbs. of phosphorus from its surrounding watershed under existing land use conditions. Under future land use and similar meteorologic conditions, Lake Lucy would, according to model output, receive 229 lbs. of phosphorus, an increase of 49 percent. During the same water year, Lake Ann received approximately 69 lbs. of phosphorus under existing land use conditions. Under future conditions, Lake Ann would receive 149 lbs. of phosphorus—an increase of 114 percent. Table 6 shows the difference in phosphorus loading for the water year 1996-1997 in each of the Lake Lucy and Lake Ann conveyance systems. Systems that show large increases in phosphorus loading coincide with those areas that will experience significant increases in impervious area as development continues. Because future land use conditions in the Lake Lucy and Lake Ann watersheds will increase lake phosphorus loadings significantly, it is important to evaluate which management practices can mitigate these elevated loadings. Graphs showing detailed information on the water quality benefits of the BMPs discussed below can be found in Appendix E.

The annual amount of phosphorus added to Lake Lucy and Lake Ann under future land use conditions from their surrounding watersheds was estimated for four climatic conditions, previously shown to affect the lake's volume, outflow volume, and hydrologic residence time (See Section 1.2 of this report):

- **Wet year**—an annual precipitation of 41 inches, the amount of precipitation occurring during the 1983 water year
- **Model calibration year**—an annual precipitation of 34 inches, the amount of precipitation occurring during the 1997 water year (The model calibration year is the year in which data were collected from the lake. The data were used to calibrate the P8 model and in-lake model.)
- **Average year**—an annual precipitation of 27 inches, the amount of precipitation occurring during the 1995 water year
- **Dry year**—an annual precipitation of 19 inches, the amount of precipitation occurring during the 1988 water year

Seven conveyance systems discharge into Lake Lucy (Figure 8). Each system adds a different amount of phosphorus to the lake based on the size, land use and stormwater treatment in each subwatershed of the conveyance system. All of the stormwater conveyed to Lake Lucy (except that from LU-A4.1 and LU-A4.2) is treated by at least one constructed pond or wetland before it is discharged into the lake.

Table 6: Total Phosphorus Load from Each Stormwater Conveyance System (Lake Lucy and Lake Ann under Existing and Future (Year 2020) Land Use Conditions)

Lake Lucy

Stormwater Conveyance System*	Existing Land Use Total Phosphorus Load (lbs)	Future (Year 2020) Land Use (Assuming All Wetlands are Preserved) Total Phosphorus Load (lbs)	Percent Increase
LU-A1.11	60.4	65.2	8%
LU-A2.3	4.2	15.2	264%
LU-A2.6b	4.4	9.9	124%
LU-A3.5	60.8	61.5	1%
LU-A4.1	0.3	3.7	1178%
LU-A4.2	1.2	4.1	257%
LU-A5.15	22.2	69.2	212%
Total	153.3	228.8	49%

Lake Ann

Stormwater Conveyance System*	Existing Land Use Total Phosphorus Load (lbs)	Future (Year 2020) Land Use (Assuming All Wetlands are Preserved) Total Phosphorus Load (lbs)	Percent Increase
LA-A1.1 Through LA1.10	13.0	56.9	337%
Load From Lake Lucy	56.3	91.8	63%
Total	69.3	148.7	114%

* The conveyance systems are named for the terminating watershed that conveys the stormwater (via overland or wetland) to the lake (See Figure 8).

Most of the water from the subwatersheds in Lake Ann is untreated before it discharges into the lake. Only one watershed (LA-A1.1) has a wetland large enough to provide treatment of its stormwater runoff.

Wetlands in the Lake Lucy and Lake Ann watersheds are classified by the City of Chanhassen as: Natural or Agricultural/Urban (Table 5). There are four subwatersheds in the Lake Lucy watershed that have wetlands that are classified as DNR-Protected Waters: LU-A1.11, LU-A2.3, LU-A5.15 and LU-A6.3 (Lake Harrison). Agricultural/Urban wetlands have already been altered or degraded to some degree, so while they still classify as wetlands under the City's "no net loss" policy, they would require lower levels of protection than wetlands classified as "Natural."

In its Surface Water Management Plan, the City of Chanhassen puts special emphasis on preserving and enhancing all DNR-Protected wetlands. Therefore, it is reasonable to assume that these wetlands will exist and will continue to function under future land use conditions. It is not legally mandatory that the remaining wetlands, classified mostly as "Agricultural/Urban" be retained with in the Lake Lucy and Lake Ann watersheds. However, preserving them could provide a substantial amount of water quality treatment for stormwater that discharges to Lake Lucy and Lake Ann. Consequently, preservation of all existing wetlands was the first management option investigated in this use attainability analysis.

- **Preserve (All)**—Comparing future phosphorus loadings to each lake with and without preservation all existing wetlands (versus preserving only "DNR-Protected" wetlands) revealed that wetlands play a significant role in the treatment of stormwater in these watersheds, reducing future phosphorus loadings by 34 percent in Lake Lucy and by 22 percent in Lake Ann during the wet water year (1982-1983) (Table 7). As a result, their preservation would significantly improve the future water quality in Lake Lucy and Lake Ann. Table 7 shows the future phosphorus loadings with and without preservation of the all existing wetlands during each of the four climatic conditions evaluated in this study. The cost of preserving these wetlands depends on the District's options in protecting them. If voluntary or required protections for the wetlands are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

Because preservation of all of the existing wetlands has such a positive impact on Lake Lucy and Lake Ann, the phosphorus loadings to the lakes under subsequent BMPs will be compared to this option (Preserve (All)) in this report.

The phosphorus load to Lake Lucy and Lake Ann may be further reduced by management practices such as upgrading and adding detention basins. The new rules being proposed for the Riley-Purgatory-Bluff Creek Watershed District may require more stringent detention basin design to control runoff from impervious areas. As a part of this use attainability study, the effect of these new rules on the phosphorus load to Lake Lucy and Lake Ann was investigated. Specifically, detention basins proposed in areas of new developments were "designed' to have a wet detention volume from 2.5 inches of runoff over the individual subwatershed (Individual Pond) or group of subwatersheds (Regional pond) for which the pond is designed. In addition, each proposed pond modeled in this study had an extended detention volume equal to 2.85 inches of runoff over the subwatershed(s) to be treated. This extended detention storage was held for 72 hours. Average depth of the wet detention was a minimum of 4 feet, and the surface area of wet detention ponds was always at least one-quarter acre.

The particulate and soluble portions of the phosphorus load from each conveyance system was evaluated to determine the feasibility of reducing the phosphorus load by adding or upgrading ponds in the Lake Lucy watershed. Detention basins remove particulate phosphorus through the settling of particulate material. Soluble or dissolved phosphorus is primarily removed by algal growth in ponds, however, because detention basins generally detain water for relatively short periods of time, these basins remove a small percentage of dissolved phosphorus. According to P8 results, the conveyance system terminating in LU-A3.5 contributes a high fraction of particulate phosphorus because the Agricultural/Urban wetland in LU-A3.4 does not have enough wet detention to adequately treat all of the stormwater that it receives. The conveyance system terminating in LU-A1.11 also yields a high fraction of particulate phosphorus because the runoff from many of its upstream watersheds is not currently treated.

- **Preserve (All) Upgrade (1) Add (1)**—Model simulations were completed to estimate the reduction in phosphorus load to Lake Lucy and Lake Ann if the Agricultural/Urban wetland in LU-A3.4 was upgraded to provide more wet detention and if a regional pond was added to LU-A1.10. Following these changes, the amount of phosphorus added to the lakes from the stormwater conveyance systems would range from 27 to 58 lbs. for Lake Lucy and 1 to 14 lbs. for Lake Ann (Table 8). Upgrading the wet detention in the wetland in LU-A3.4 could potentially be accomplished two ways: by raising the outlet elevation, or by excavation. Before raising the outlet elevation, however, low floor elevations of the surrounding homes and buildings would have to be evaluated to ensure that these structures would not be threatened by flooding. If excavation is necessary, the cost of upgrading the wetland is estimated to be $112,300. The cost of adding a pond to LU-A1.10 is estimated to be $83,000.

Table 7: Phosphorus Loading Reduction from Preservation of all Wetlands in the Lake Lucy and Lake Ann Watersheds

	Annual Total Phosphorus Load In Pounds Future Land Use Conditions		
	Only DNR Protected Wetlands Preserved	All Wetlands Preserved	Phosphorus Removed
Lake Lucy Watershed			
Wet (41" of precipitation)	691	453	238
Model Calibration (34" of precipitation)	401	229	173
Average (27"of precipitation)	337	194	142
Dry (19" of precipitation)	250	145	105
Lake Ann Watershed			
Wet (41" of precipitation)	354	276	78
Model Calibration (34" of precipitation)	202	149	54
Average (27"of precipitation)	143	108	36
Dry (19" of precipitation)	51	43	8

Table 8: Phosphorus Loading Reduction from Upgrade (1) and Addition of Pond (1) in the Lake Lucy and Lake Ann Watersheds (Assuming All Wetlands are Preserved)

	Annual Total Phosphorus Load In Pounds Future Land Use Conditions		
	All Wetlands Preserved	Plus Upgrade Pond in LU-A3.4 and Add Pond in LU-A1.10	Phosphorus Removed
Lake Lucy Watershed			
Wet (41" of precipitation)	453	395	58
Model Calibration (34" of precipitation)	229	205	24
Average (27"of precipitation)	194	159	36
Dry (19" of precipitation)	145	118	27
Lake Ann Watershed			
Wet (41" of precipitation)	276	262	14
Model Calibration (34" of precipitation)	149	143	6
Average (27"of precipitation)	108	102	6
Dry (19" of precipitation)	43	42	1

P:\23\27\053\ela\TP_Loads.xls

Additional ponds in the Lake Ann watershed would also serve to decrease phosphorus loads, though only to Lake Ann. Subwatersheds LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7 and LA-A1.9 would benefit from detention ponds because they will be the most developed Lake Ann subwatersheds under future land use conditions.

- **Preserve (All) Upgrade (1) Add (6)**—In addition to the ponds proposed for LU-A3.4 and LU-A1.10, the effect of these five ponds in the Lake Ann watershed was evaluated with the model. The reduction of phosphorus load to Lake Lucy remains the same (no additional treatment provided in this option). Loads to Lake Ann, however, are reduced by 21 to 60 lbs. (Table 9). The cost of adding these five ponds is estimated to be $143,000.

By the time that runoff from Lake Lucy's LU-A5.15 conveyance system reaches the lake, its phosphorus load is primarily soluble. However, adding ponds upstream of subwatershed LU-A5.15 could still benefit the water quality of Lake Lucy and Lake Ann in two ways: (1) Detention ponds would provide some treatment through infiltration of stormwater, and (2) Upland detention ponds in the LU-A5.15 conveyance system would serve to treat stormwater before it reached the DNR-Protected wetland in LU-A5.15. This is consistent with the City's wish to protect and enhance all DNR-Protected Waters.

An assessment of the five constructed wet detention basins in the Lake Lucy watershed was also completed to determine whether the constructed ponds currently meet the minimum criteria established by the MPCA (MPCA, 1989) and NURP criteria (i.e., based upon results from the Nationwide Urban Runoff Program). Current criteria by the MPCA and NURP require a minimum permanent pool or dead storage volume for each pond based upon its watershed size. As discussed previously, the treatment effectiveness of a pond is directly related to its dead storage volume. Development plans were used to estimate the dead storage volumes of these basins. All ponds with the exception LU-A5.2 currently meet MPCA/NURP criteria. LU-A5.2 should not only be upgraded to meet MPCA/NURP criteria; it would serve well as a regional pond that treats not only the runoff from its own watershed, but that of LU-A5.1 as well (LU-A5.1 currently receives no treatment before entering LU-A5.2).

- **Preserve (All) Upgrade (2) Add (12)**—Model simulations were completed to estimate the reduction in phosphorus loading to Lake Lucy and Lake Ann if the proposed pond upgrades and additions were implemented as discussed above and if the pond in LU-A5.2 was upgraded and ponds were added in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13 and LU-A5.14. Following these changes, the amount of phosphorus added to the lakes would range from 43 to 89 lbs. for Lake Lucy and 21 to 68 lbs.

for Lake Ann (Table 10). Upgrading the pond in LU-A5.2 is estimated to cost $36,000. Adding the six upland basins in the LU-A5.15 conveyance system is estimated to cost $123,000.

Diverting a portion of the lake's watershed runoff into retention areas where the runoff can seep into the ground (infiltration) will reduce the phosphorus load conveyed to the lake by the stormwater conveyance systems. Infiltration facilities include infiltration basins, infiltration trenches, dry wells, porous pavement, swales with check dams, and bioretention areas (infiltration areas with vegetation designed to enhance infiltration). The new rules being proposed for the Riley-Purgatory-Bluff Creek Watershed District may require that new developments provide infiltration basins to control runoff from impervious areas. As a part of this use attainability study, the effect of this new rule on the phosphorus load to Lake Lucy and Lake Ann was investigated. Infiltration basins were designed as prescribed by the proposed rules, based on soil type and the acreage of new impervious area (the difference between existing impervious area and future (Year 2020) impervious area in each subwatershed. Only subwatersheds that will experience an increase of more than 1 acre of impervious area were assumed to need infiltration basins for the purposes of this study.

- **Preserve (All) Upgrade (2) Add (12) Store**—Model simulation was completed to estimate the removal effectiveness of basins in addition to the proposed pond additions and upgrades suggested in Preserve (All) Upgrade (2) Add (12). Under these conditions, the amount of phosphorus removed from stormwater conveyance systems in the Lake Lucy watershed would range from 69 to 155 pounds under varying climatic conditions. The amount of phosphorus removed from stormwater conveyance systems in the Lake Ann watershed would range from 31 to 104 pounds under varying climatic conditions (Table 11). Design and construction of infiltration basins throughout the Lake Lucy and Lake Ann watersheds is estimated to cost $50,000 in the Lake Lucy watershed and $13,500 in the Lake Ann watershed. This cost assumes no land acquisition costs or anticipated annual maintenance costs.

All of the proposed detention pond additions, detention pond/wetland upgrades and infiltration basin information are listed in Tables 12a and 12b. Locations of these proposed projects are shown in Figure 9.

2.2.3 Public Ditch Systems

There are no known public ditch systems affecting Lake Lucy and Lake Ann.

Table 9: Phosphorus Loading Reduction from Upgrade of Pond (1) and Addition of Ponds (6) in the Lake Lucy and Lake Ann Watersheds. (Assuming All Wetlands are Preserved)

	Annual Total Phosphorus Load In Pounds Future Land Use Conditions		
	All Wetlands Preserved	Plus Upgrade Pond in LU-A3.4 and Add Ponds in LU-A1.10, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9	Phosphorus Removed
Lake Lucy Watershed			
Wet (41" of precipitation)	453	395	58
Model Calibration (34" of precipitation)	229	205	24
Average (27"of precipitation)	194	159	36
Dry (19" of precipitation)	145	118	27
Lake Ann Watershed			
Wet (41" of precipitation)	276	216	60
Model Calibration (34" of precipitation)	149	112	37
Average (27"of precipitation)	108	74	34
Dry (19" of precipitation)	43	22	21

Table 10: Phosphorus Loading Reduction from Upgrade of Ponds (2) and Addition of Ponds (12) in the Lake Lucy and Lake Ann Watersheds (Assuming All Wetlands are Preserved).

	Annual Total Phosphorus Load In Pounds Future Land Use Conditions		
	All Wetlands Preserved	Plus Upgrade Pond in LU-A3.4 and LU-A5.2 Add Ponds in LA-A1.2, LA-A1.3 LA-A1.5, LA-A1.7, LA-A1.9 LU-A1.10, LU-A5.4, LU-A5.10 LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14	Phosphorus Removed
Lake Lucy Watershed			
Wet (41" of precipitation)	453	365	89
Model Calibration (34" of precipitation)	229	184	45
Average (27"of precipitation)	194	140	55
Dry (19" of precipitation)	145	102	43
Lake Ann Watershed			
Wet (41" of precipitation)	276	208	68
Model Calibration (34" of precipitation)	149	107	42
Average (27"of precipitation)	108	71	37
Dry (19" of precipitation)	43	21	21

Table 11: Phosphorus Loading Reduction from Upgrade of Ponds (2) and Addition of Ponds (12) and Storage of Stormwater in Infiltration Basins throughout the Lake Lucy and Lake Ann Watersheds (Assuming All Wetlands are Preserved).

	Annual Total Phosphorus Load In Pounds Future Land Use Conditions		
	All Wetlands Preserved	Plus Upgrade Pond in LU-A3.4 and LU-A5.2 Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9, LU-A1.10, LU-A5.4, LU-A5.10 LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14 Store Stormwater in Infiltration Basins	Phosphorus Removed
Lake Lucy Watershed			
Wet (41" of precipitation)	453	298	155
Model Calibration (34" of precipitation)	229	140	89
Average (27"of precipitation)	194	101	94
Dry (19" of precipitation)	145	75	69
Lake Ann Watershed			
Wet (41" of precipitation)	276	172	104
Model Calibration (34" of precipitation)	149	101	48
Average (27"of precipitation)	108	51	56
Dry (19" of precipitation)	43	12	31

Table 12a: Proposed Pond Upgrades, Pond Additions and Infiltration Basins in the Lake Lucy Watershed

Upgraded Pond in Subwatershed:	Dead Storage Volume (acre-ft)	Dead Storage Average Depth (ft)	Extended Detention Volume (acre-ft)	Retro-Fit or New Development?[1]	Individual or Regional?[2]
LU-A3.4	8.7	4	9.8	Retro-Fit	Regional
LU-A5.2	1.1	5.0	1.6	New Development	Regional

Added Pond in Subwatershed:	Dead Storage Volume (acre-ft)	Dead Storage Average Depth (ft)	Extended Detention Volume (acre-ft)	Retro-Fit or New Development?[1]	Individual or Regional?[2]
LU-A1.10	2.5	4.0	4.0	Retro-Fit/New Development	Regional
LU-A5.4	0.2	4.0	0.3	New Development	Individual
LU-A5.10	1.1	5.0	1.6	New Development	Regional
LU-A5.11	0.6	4.0	0.9	New Development	Individual
LU-A5.12	0.2	4.0	0.3	New Development	Individual
LU-A5.13	0.5	5.0	0.7	New Development	Regional
LU-A5.14	0.6	4.0	0.8	New Development	Individual
LU-A6.1	0.4	4.0	0.5	New Development	Individual
LU-A6.2	0.3	4.0	0.5	New Development	Individual

[1] Retro-Fit ponds are designed based on the MPCA Best Management Practaces in areas that are already developed under existing watershed conditions. New Development Ponds are designed with the MPCA Best Management Practaces in areas that are not currently developed, but will be developed under future land use conditions.

[2] These ponds are either "Individual" (sized for one subwatershed's drainage) or "Regional" (sized to accommodate the drainage from several subwatersheds).

Infiltration Basins in Subwatershed:	Infiltration Basin Average Depth (inches)	Total Infiltration Volume (acre-ft)
LU-A1.10	8.5	0.1
LU-A2.2	8.5	0.1
LU-A2.3	8.5	0.1
LU-A2.4	8.5	0.2
LU-A2.6b	13.5	0.2
LU-A3.2	8.5	0.1
LU-A4.1	13.5	0.1
LU-A4.2	8.5	0.1
LU-A5.2	8.5	0.1
LU-A5.6	8.5	0.2
LU-A5.10	8.5	0.4
LU-A5.11	8.5	0.2
LU-A5.12	8.5	0.1
LU-A5.13	8.5	0.2
LU-A5.14	8.5	0.2
LU-A5.15	11	0.9
LU-A6.1	8.5	0.1
LU-A6.2	8.5	0.1
LU-A6.3	8.5	0.4

Table 12b: Proposed Pond Additions and Infiltration Basins in the Lake Ann Watershed

Added Pond in Subwatershed:	Dead Storage Volume (acre-ft)	Dead Storage Average Depth (ft)	Extended Detention Volume (acre-ft)	Retro-Fit or New Development?[1]	Individual or Regional?[2]
LA-A1.2	0.3	4.0	0.4	New-Development	Regional
LA-A1.3	0.5	4.0	0.7	New-Development	Individual
LA-A1.5	0.4	4.0	0.6	New-Development	Individual
LA-A1.7	0.5	4.0	0.7	New-Development	Individual
LA-A1.9	0.2	4.0	0.2	New-Development	Individual

[1] Retro-Fit ponds are designed based on the MPCA Best Management Practaces in areas that are already developed under existing watershed conditions. New Development Ponds are designed with the MPCA Best Management Practaces in areas that are not currently developed, but will be developed under future land use conditions.

[2] These ponds are either "Individual" (sized for one subwatershed's drainage) or "Regional" (sized to accommodate the drainage from several subwatersheds).

Infiltration Basins in Subwatershed:	Infiltration Basin Average Depth (inches)	Total Infiltration Volume (acre-ft)
LA-A1.1	8.5	0.1
LA-A1.2	8.5	0.1
LA-A1.3	8.5	0.2
LA-A1.7	8.5	0.3
LA-A1.8	8.5	0.2
LA-A1.9	8.5	0.1
LA-A1.10	8.5	0.1

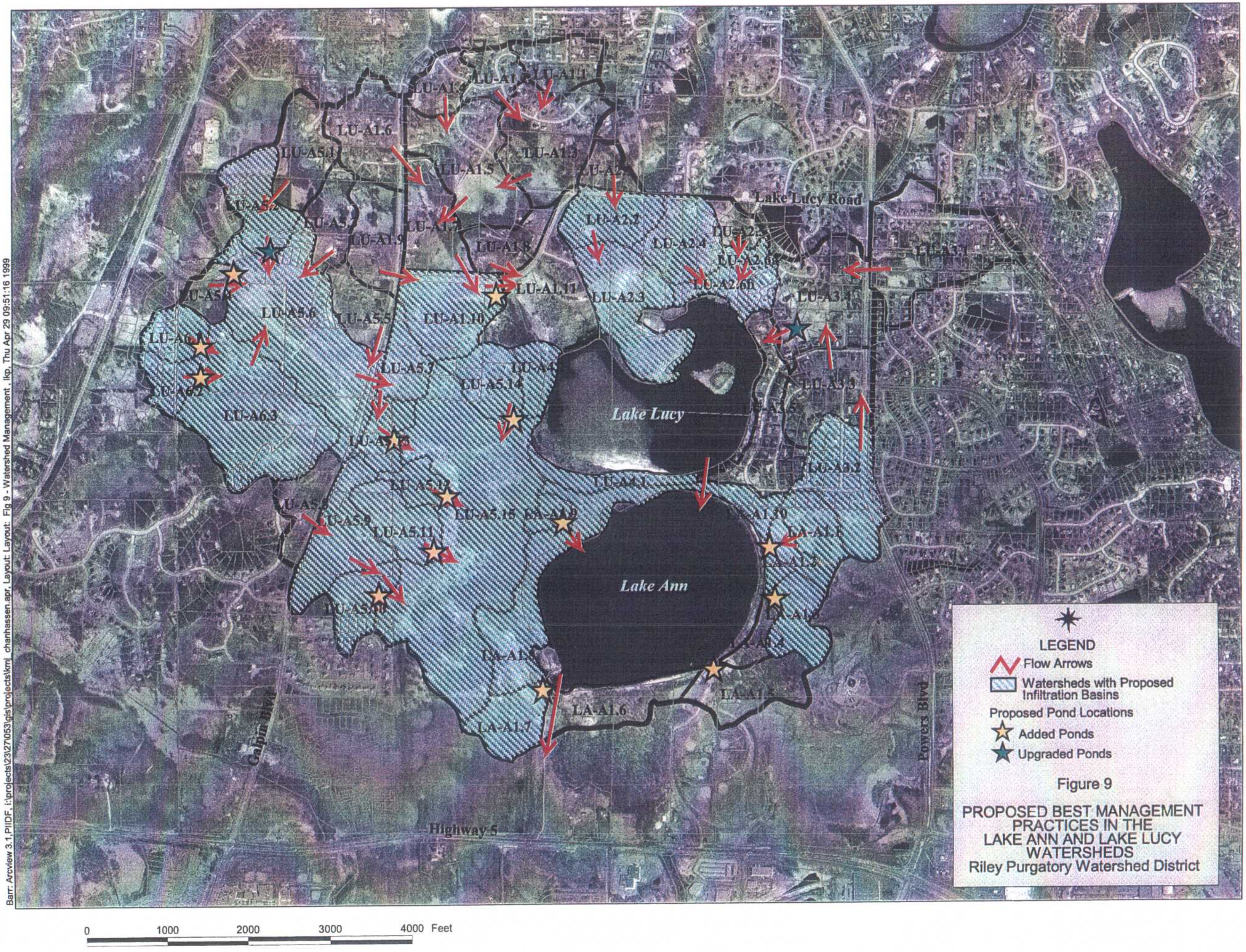


Figure 9

PROPOSED BEST MANAGEMENT PRACTICES IN THE LAKE ANN AND LAKE LUCY WATERSHEDS

Riley Purgatory Watershed District

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2.3 Fish and Wildlife Habitat

The fisheries and wildlife habitat in Lake Lucy and Lake Ann are currently considered satisfactory (Ellison, 1999; Hoffman, 1999). However, under future land use conditions, additional measures will be needed to maintain or enhance the current fisheries habitat.

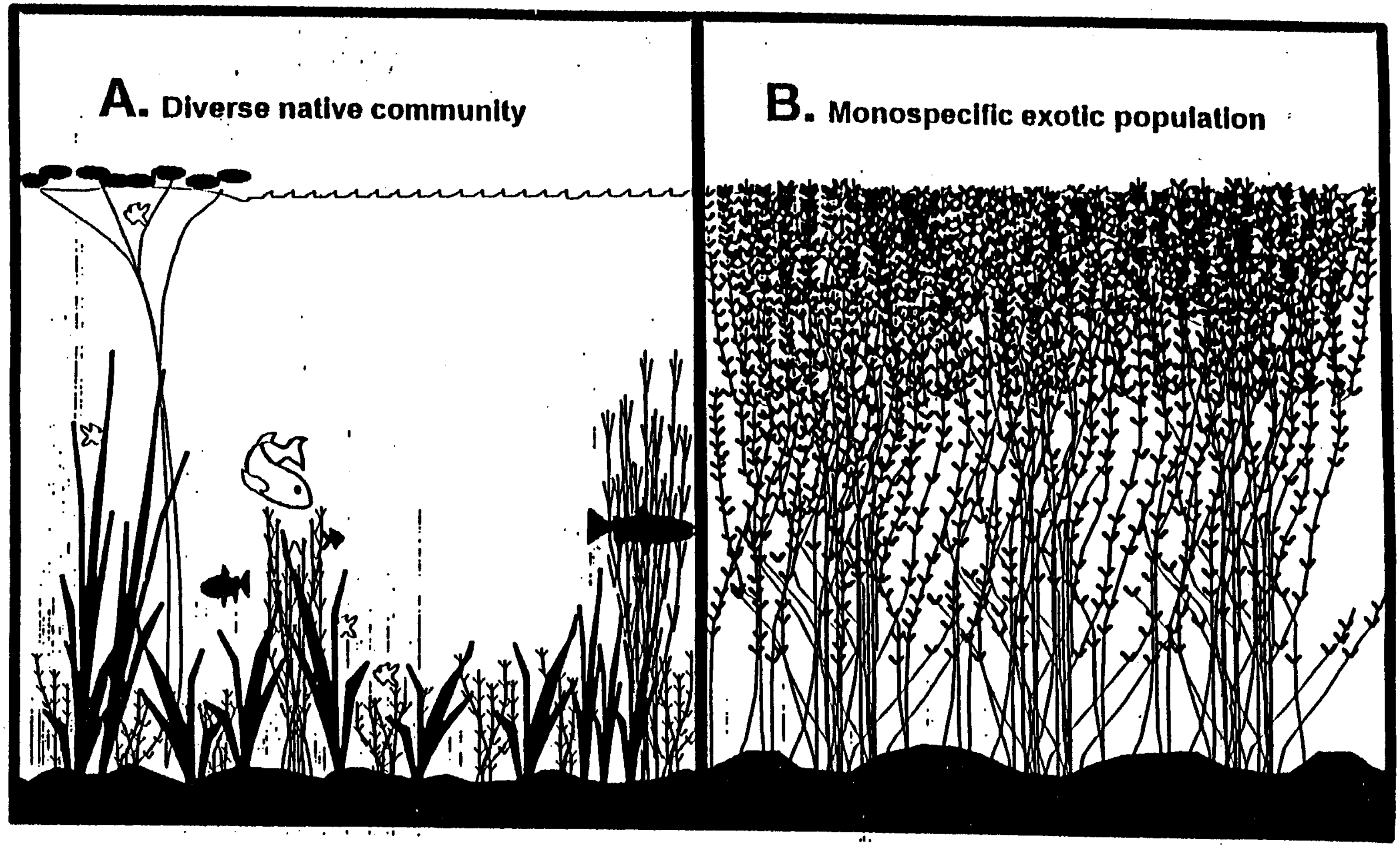
All of the measures discussed in Section 2.2.2 of this report, "Stormwater Conveyance Systems" would benefit the fisheries in Lake Lucy and Lake Ann. Decreasing the phosphorus load to these lakes improves water quality for fisheries by decreasing algal growth and thereby increasing the transparency of the lake. Increased lake transparency allows light to penetrate further into the water column, encouraging macrophyte growth- a vital part of invertebrate and fisheries habitat.

The current macrophyte communities in Lake Lucy and Lake Ann are diverse and healthy. However, macrophyte surveys should continue on these lakes to monitor the growths of undesirable non native species. If curly-leaf pondweed *(Potamogeton crispus)* starts dominating the macrophyte community, or if Eurasian watermilfoil appears in the lakes, for example, some mitigation measures may be needed. As shown in Figure 10A, a diverse native community provides greater opportunities for predation of smaller fish than a dense growth by non-native species (also called exotic species) shown in Figure 10B. Declines in native species reduce available habitat for invertebrates and other food organisms for small fish. The estimated cost of a macrophyte survey is $1,200 per lake.

2.4 Water-Based Recreation

2.4.1 Lake Lucy

Recreational uses of Lake Lucy currently include fishing and boating. Fishing is the primary recreation use. Under current conditions, Lake Lucy is considered to have a good fishery (Ellison, 1999). However, in the future, increased phosphorus loadings from developments around the lake could threaten that fishery. Phosphorus reduction can be attained by implementing the management practices discussed in Section 2.2.2 of this report, "Stormwater Conveyance Systems" (preserve, upgrade, add, and store management practices). In addition, some management strategies could be implemented to enhance the fishery in Lake Lucy.



Source: Smart et al., 1996

Figure 10A and 10B

SUBMERSED AQUATIC PLANT COMMUNITIES

- **Manage (1)**—Lake Lucy experiences occasional winterkills, approximately every 10 years (Ellison, 1999), a point of some concern for the people who fish on Lake Lucy. However, some fisheries biologists believe that allowing natural, infrequent winterkills can be a useful fisheries management tool. Winterkills can control the growth of some undesirable species naturally while strengthening the growth of others by naturally removing the weaker fish in a population. Lake Lucy, for example had a strong, healthy fishery this year after a harsh winterkill only a few years ago (Ellison, 1999). It is possible that a harsh winterkill could degrade a lake's fishery the year after it occurs. However, if Lake Lucy's fishery was significantly degraded after a winterkill, sport fish such as largemouth bass (particularly sensitive to low oxygen levels) could be stocked at an estimated cost of $2,500.

- **Manage (2)**—There are a high number of small black bullheads in Lake Lucy. If these fish become a concern, commercial anglers could be hired to remove the bullheads for an estimated cost of $1,000 (for one day's work). This technique has been used with some success in other lakes in the watershed district in the past.

- **Manage (3)**—Finally, another option to enhance the recreational use of Lake Lucy would be to install a fishing pier to allow greater fishing access for the community. Fishing pier costs can vary greatly, depending on the size of the pier and how difficult it is to install. The estimated price of an 84-foot pier (T-shaped) is $18,000. Building a public access is another option for Lake Lucy. In the past, the lack of a public access on this lake has limited DNR management. There is no estimate for the cost of building a public access on Lake Lucy at this time.

2.4.2 Lake Ann

Recreation uses of Lake Ann currently include, fishing, boating, and aesthetic viewing. However, swimming is its primary recreational use. The MPCA has established water quality criteria to determine whether a lake has the water quality required to fully support a swimmable use. According to MPCA criteria, lakes fully supporting the swimmable use should exhibit "impaired swimming" conditions less than 10 percent of the time and in terms of physical condition should exhibit "high algal levels" less than 10 percent of the time. To put this criteria in measurable terms, the MPCA has specified that lakes with an average Trophic State Index (TSI) < 53 are classified as fully supporting swimmable and aesthetic uses. The trophic state index is calculated from total phosphorus, chlorophyll *a*, and Secchi disc transparency data from a lake (Carlson, 1977). When the MPCA criteria for fully swimmable and aesthetic uses are compared to a standardized lake rating system, a TSI < 53 would correspond to oligotrophic (excellent water quality), mesotrophic (good water quality), and mildly eutrophic (poor water quality) conditions. An evaluation of estimated Lake Ann future TSI under wet, dry, average and model calibration year (i.e., water year 1997) climatic conditions indicates the lake will be able to fully support swimmable use under all climatic conditions if all existing wetlands are preserved. If only the "DNR Protected" wetlands are preserved, the lake would not be able to fully support swimming during average year.

Lake Ann can further improve water quality to enhance recreational conditions by reducing phosphorus loads to the lake. Phosphorus reduction can be attained by implementing the management practices discussed in Section 2.2.2 of this report, "Stormwater Conveyance Systems" (preserve, upgrade, add, and store management practices).

2.5 Ecosystem Data

The Lake Lucy and Lake Ann ecosystems are currently satisfactory. They have good fisheries (relative to other lakes in their lake classes) and their zooplankton communities appear to be balanced and healthy. The presence of blue-green algae in the phytoplankton communities causes some concern, indicating that the lakes have the potential for noxious blooms in late summer. This concern is even greater under future land use conditions, as phosphorus loadings are bound to increase.

Balance to the lakes' ecosystem may be maintained under future land use conditions by reducing phosphorus loads to the lake and management of the lakes' fisheries. Phosphorus reduction can be attained by implementing the management practices discussed in Section 2.2.1 of this report, "Natural Conveyance Systems," and Section 2.2.2 "Stormwater Conveyance Systems."

2.6 Water Quality

2.6.1 Baseline/Current Analysis

The comparison of baseline versus current water quality in Lake Lucy and Lake Ann is discussed in Section 1.3.2 of this report "Baseline/Current Water Quality."

2.6.2 Historical Water Quality Trend Analysis

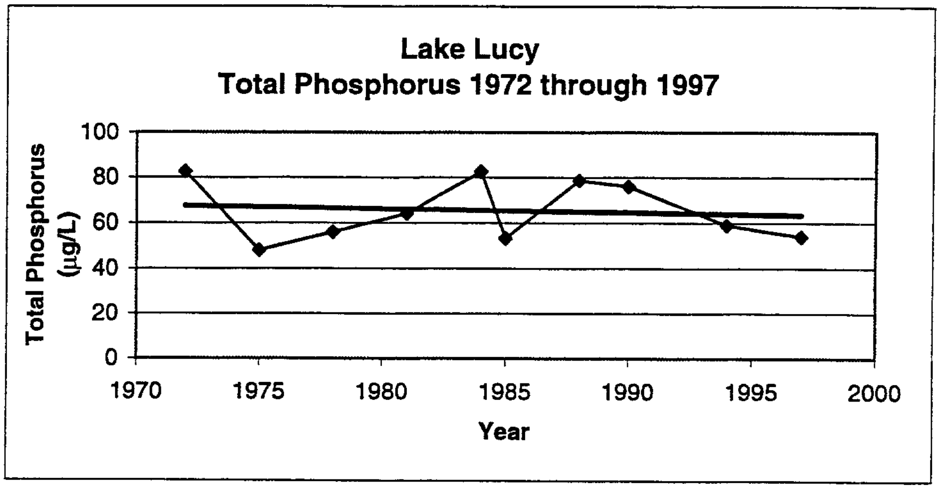
A trend analysis of Lake Lucy and Lake Ann was completed to determine if the lake had experienced significant degradation or improvement during the years for which water quality data are available. The results of the trend analysis show no significant degradation trend in the lakes' water quality from 1972 to 1997. The analysis was based upon Secchi disc transparency, total phosphorus, and chlorophyll *a* observations collected since 1972 (i.e., 10 years of data). Standard statistical methods (i.e., linear regression and analysis of variance) were used to complete the analysis. Plots of the three water quality variables and the fitted regression lines are shown in Figures 11a and 11b.

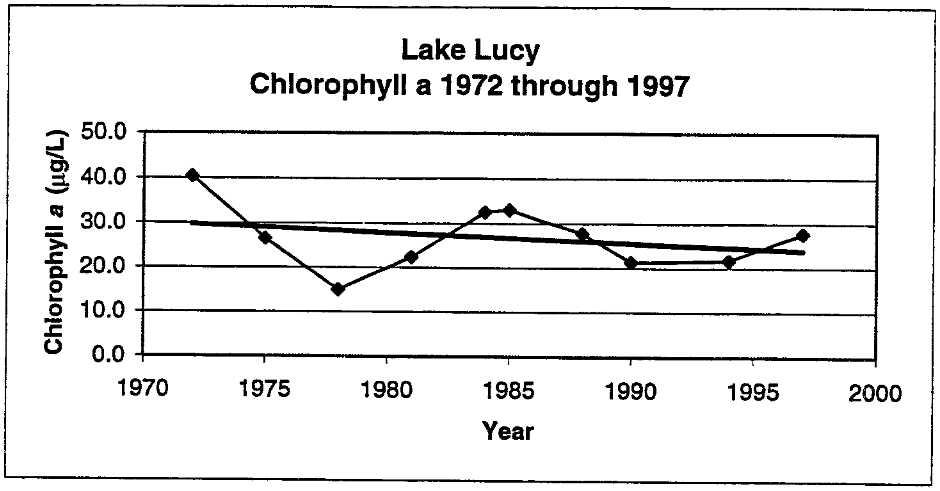
Two criteria must be met to conclude that the lake's water quality has significantly improved or declined. First, the trend in a variable is considered significant if the slope of the regression is statistically significant at the 95 percent confidence level. Second, a conclusion of degraded water quality requires concurrent increases in total phosphorus and chlorophyll *a* concentrations, and decreases in Secchi disc transparencies; a conclusion of improvement requires the inverse relationship. The results for the three variables did not fit these criteria, showing that the water quality of Lake Lucy and Lake Ann has not declined or improved significantly over time.

However, modeling results indicate that as the watersheds continue to develop, both lakes will likely experience degraded water quality unless management practices to stop the decline are identified and implemented.

2.6.3 Water Quality Modeling Analysis

During preparation of the District water management plan, the Dillon and Rigler model (Dillon and Rigler, 1974) was used to estimate lake water quality conditions. However, during the final use Attainability Analysis, it was determined that the Dillon and Rigler equation, using only external loads estimated by P8, underpredicted the summer average total phosphorus concentrations in both Lake Lucy and Lake Ann. A mass balance of phosphorus for each lake during the summer revealed that external loads alone could not account for the high summer phosphorus peaks that both lakes frequently experience. The phosphorus load discrepancy was attributed to internal loading, most likely caused by erosion of Lake Lucy's and Lake Ann's thermoclines during the summer storm season. Internal load was calculated based on a mass balance on phosphorus for each lake—60 percent of this internal load was assumed to be in a form that was available to algae. This available load, divided by the total lake volume, was added to the concentration calculated by Dillon and Rigler's equation, with Nurnberg's retention term (Nurnberg, 1998), to represent the phosphorus concentration that Lake Lucy and Lake Ann experience during 20 percent of the summer. During the remaining 80 percent of the summer, the lakes' phosphorus concentrations were assumed to be dictated by external loads alone. This breakdown of 20 percent External Load + Internal Load and 80 percent External Load was based on observations of historical total phosphorus data in both lakes. After average summer total phosphorus concentrations were calculated, MPCA relationships were used to estimate the corresponding values for chlorophyll *a* and Secchi disc transparency (Heiskary and Wilson, 1990).





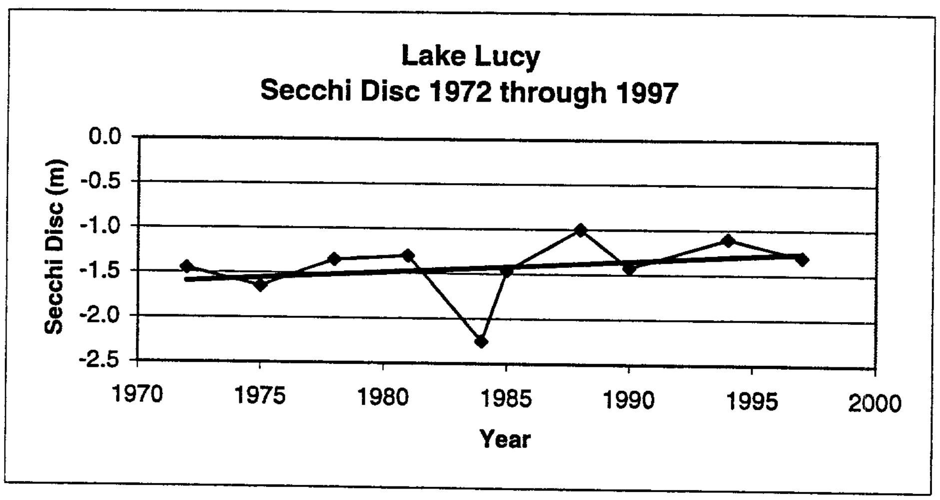


Figure 11a: Lake Lucy Trend Analysis- 1972-1997
Total Phosphorus and Chlorophyll a Concentrations and Secchi Disc Transparency
(Summer Means- June Through August)

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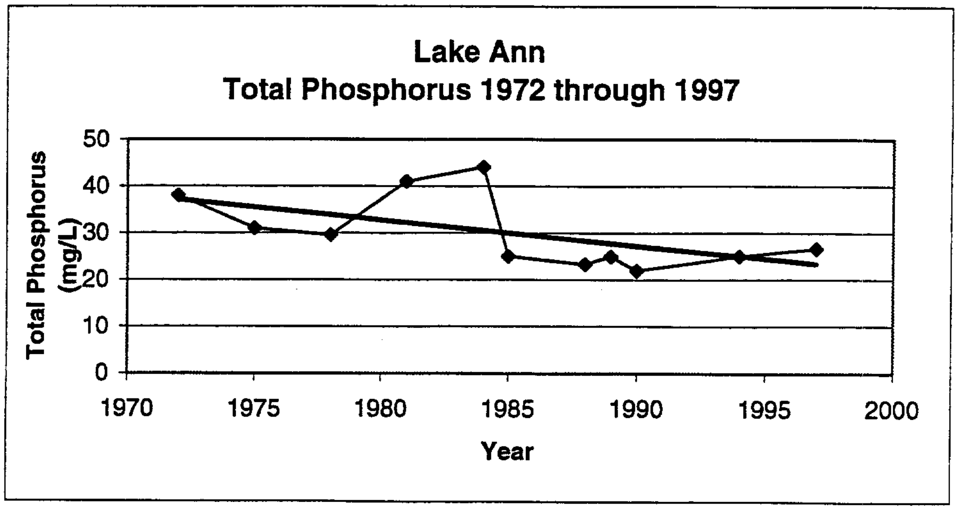

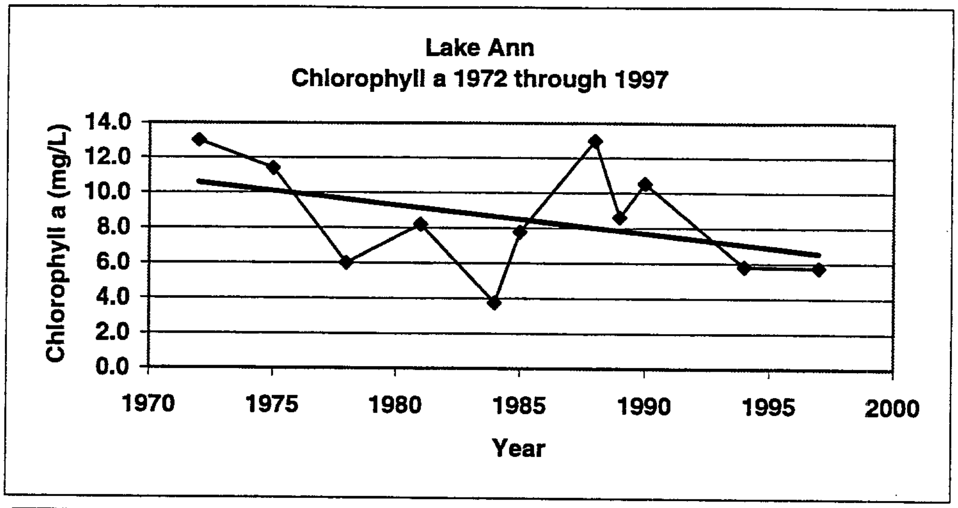

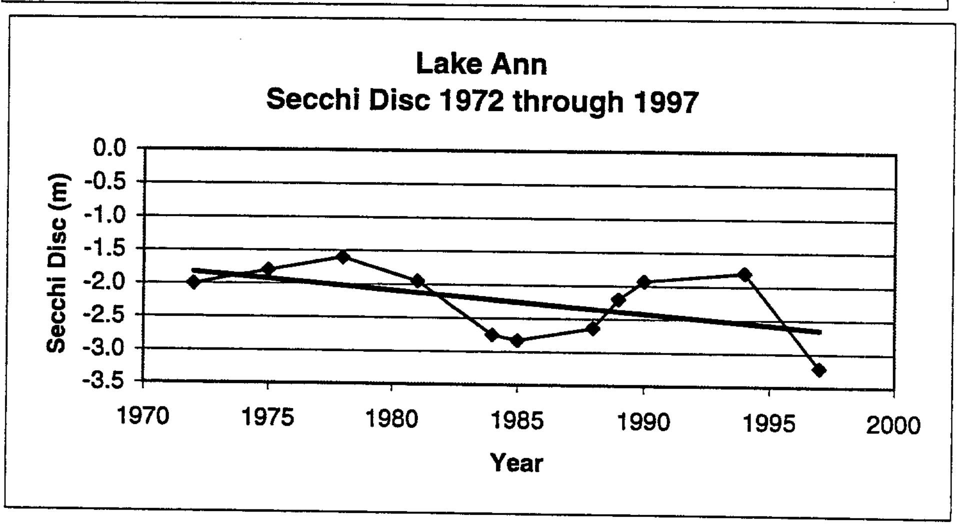

Figure 11b: Lake Ann Trend Analysis- 1972-1997
Total Phosphorus and Chlorophyll a Concentrations and Secchi Disc Transparency
(Summer Means- June Through August)

P:\23\27\053\ela\historical_TP_data.xls

2.6.3.1 Lake Lucy

The modeling analysis indicates the lake currently has poor or very poor water quality under virtually all climatic conditions with future land use conditions, even if all existing wetlands are preserved in the watershed. A comparison of the lake's modeled total phosphorus concentrations under wet, dry, average, and model calibration year (1997) climatic conditions with a standardized lake rating system indicates the average summer values were within the hypereutrophic category (i.e., very poor water quality, See Figure 12a). The lake's modeled summer average chlorophyll *a* concentrations and Secchi disc transparencies were within the eutrophic (poor water quality) or hypereutrophic (very poor water quality) categories (See Figures 13a and 14a).

2.6.3.2 Lake Ann

The modeling analysis indicates the lake currently has poor water quality under virtually all climatic conditions with future land use conditions, even if all existing wetlands are preserved in the watershed. A comparison of the lake's modeled total phosphorus concentrations under wet, dry, average, and model calibration year (1997) climatic conditions with a standardized lake rating system indicates the average summer values were within the eutrophic category (i.e., poor water quality, See Figure 12b). The lake's modeled summer average chlorophyll *a* concentrations and Secchi disc transparencies were also within the eutrophic (poor water quality) category (See Figures 13b and 14b).

The water quality in Lake Lucy and Lake Ann can be improved by reducing phosphorus loaded to the lake from their surrounding watersheds. Phosphorus reduction can be attained by implementing the management practices discussed in Section 2.2.2 of this report, "Stormwater Conveyance Systems" (preserve, upgrade, add, and store management practices).

2.7 Major Hydrologic Characteristics

The major hydrologic characteristics of both Lake Lucy and Lake Ann have likely changed since the pre-development period. Change will continue throughout the development of the watershed.

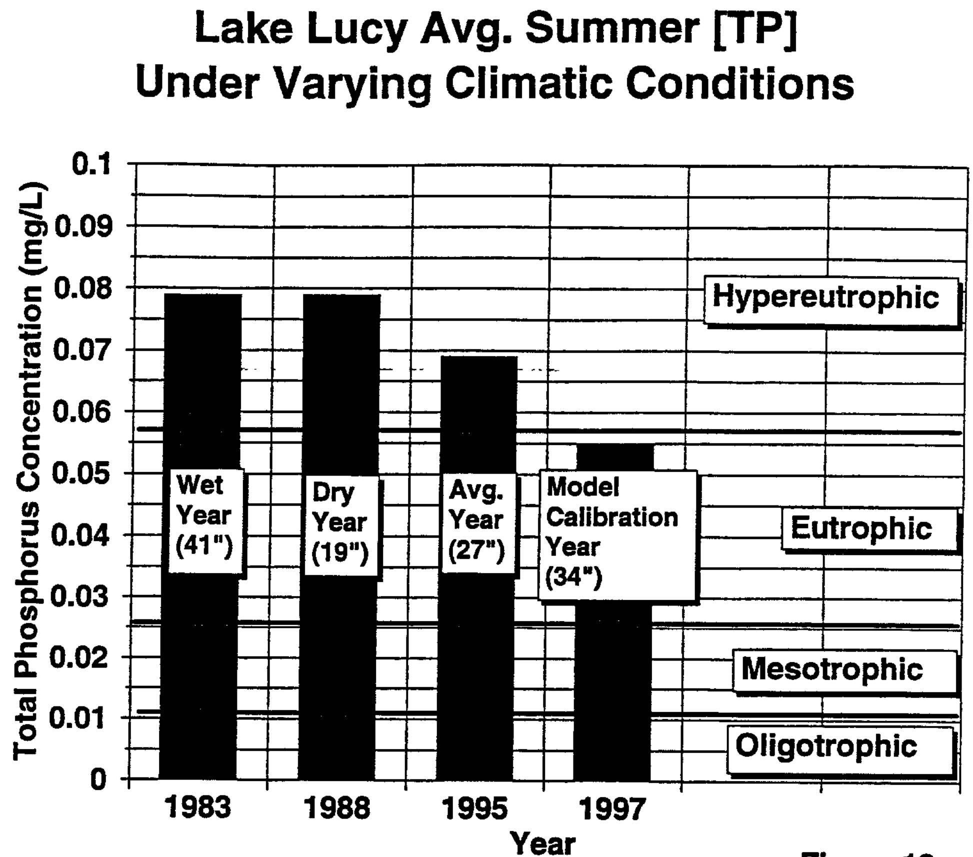

Figure 12a

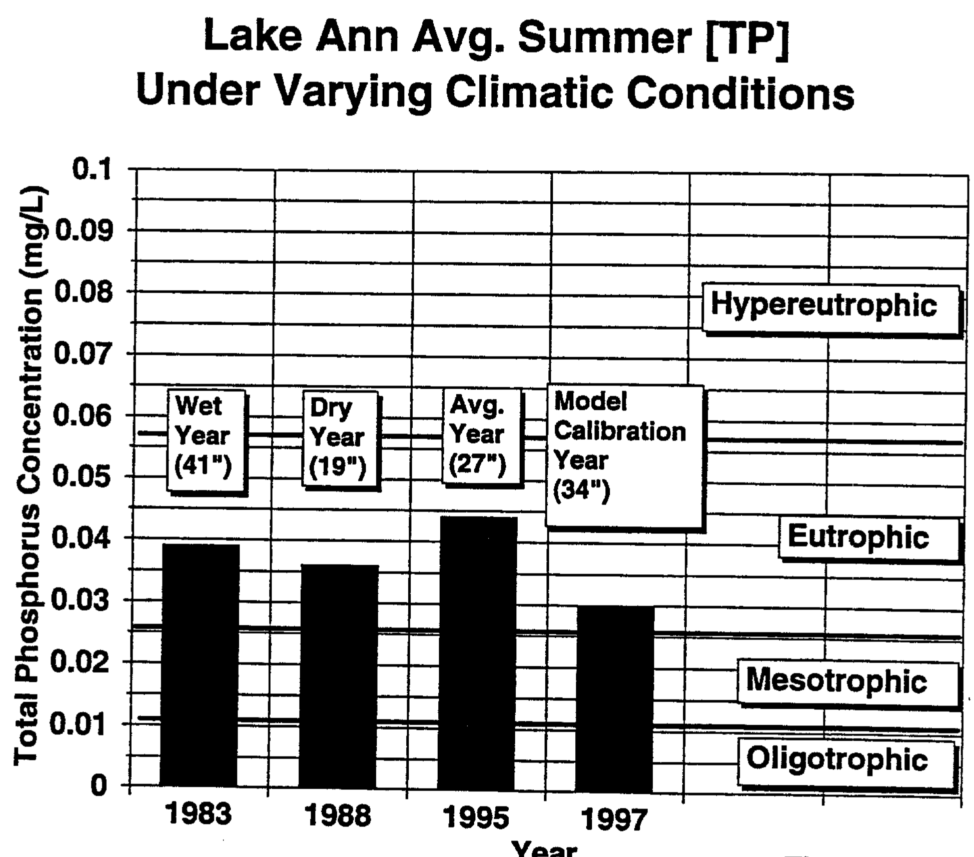

Figure 12b

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Lake Lucy Avg. Summer Chlorophyll a Under Varying Climatic Conditions

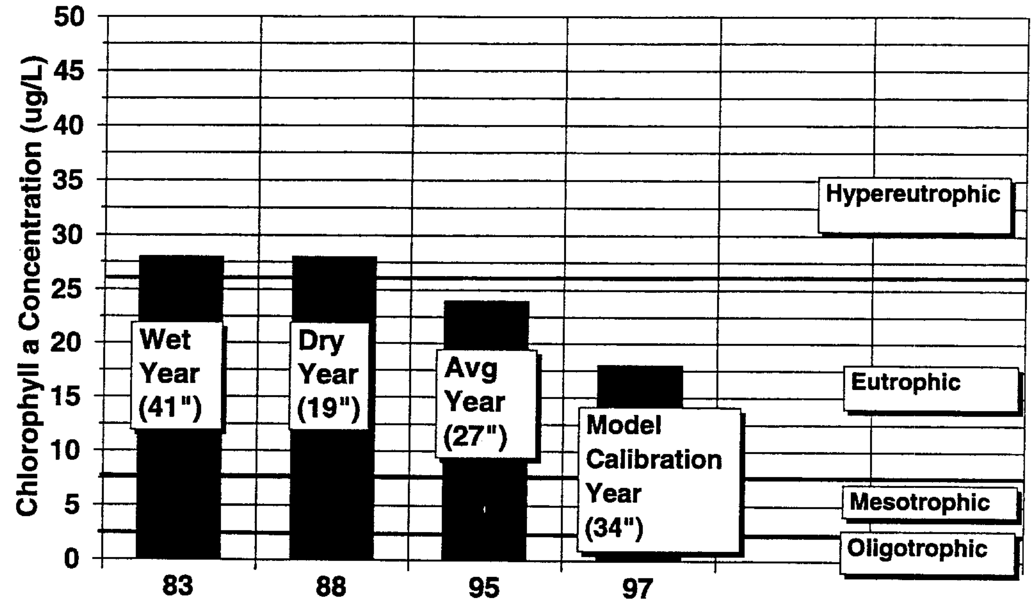

Figure 13a

Lake Ann Avg. Summer Chlorophyll a Under Varying Climatic Conditions

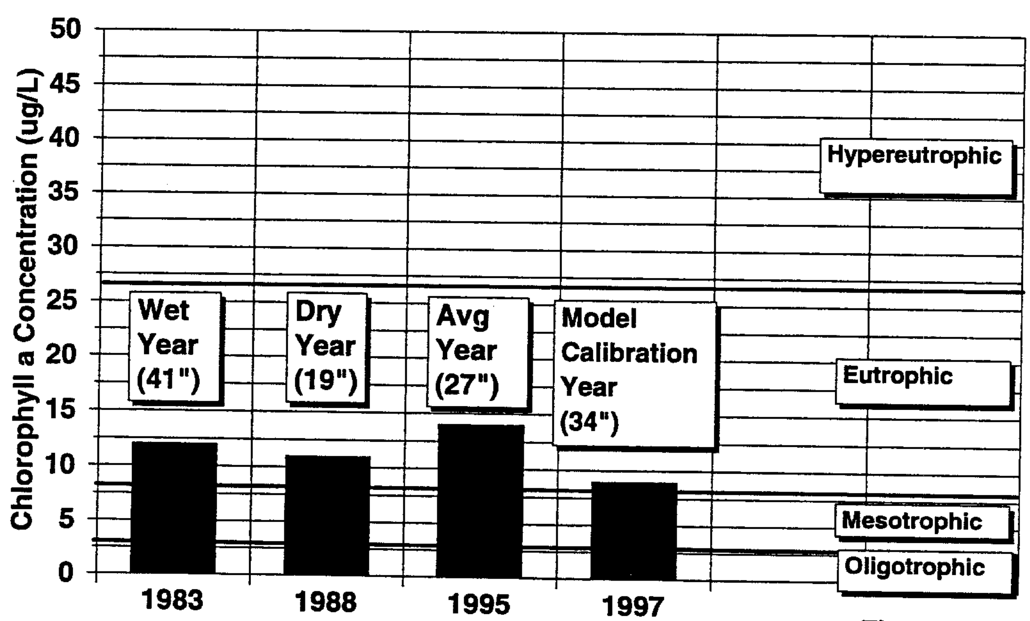

Figure 13b

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Lake Lucy Avg. Summer Secchi Disc Under Varying Climatic Conditions

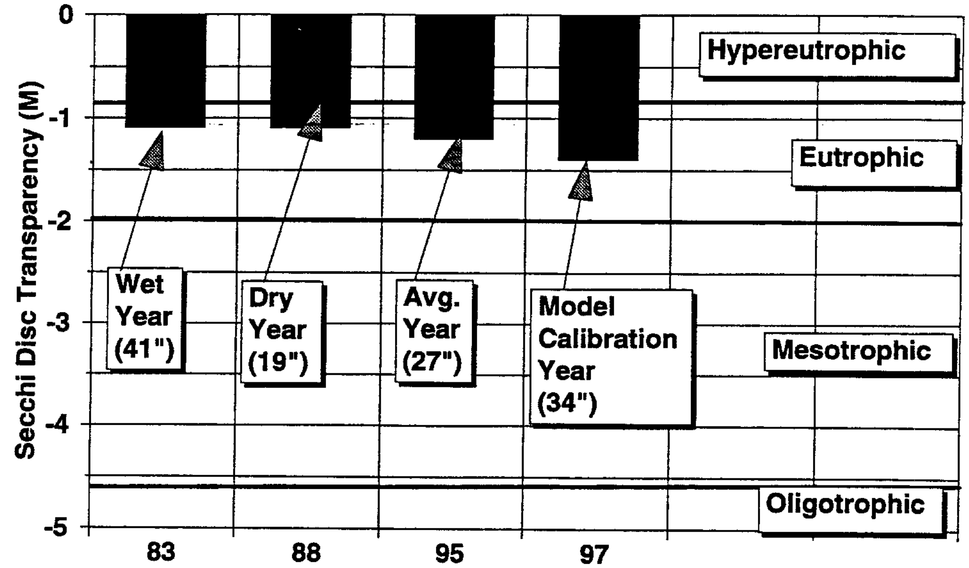

Figure 14a

Lake Ann Avg. Summer Secchi Disc Under Varying Climatic Conditions

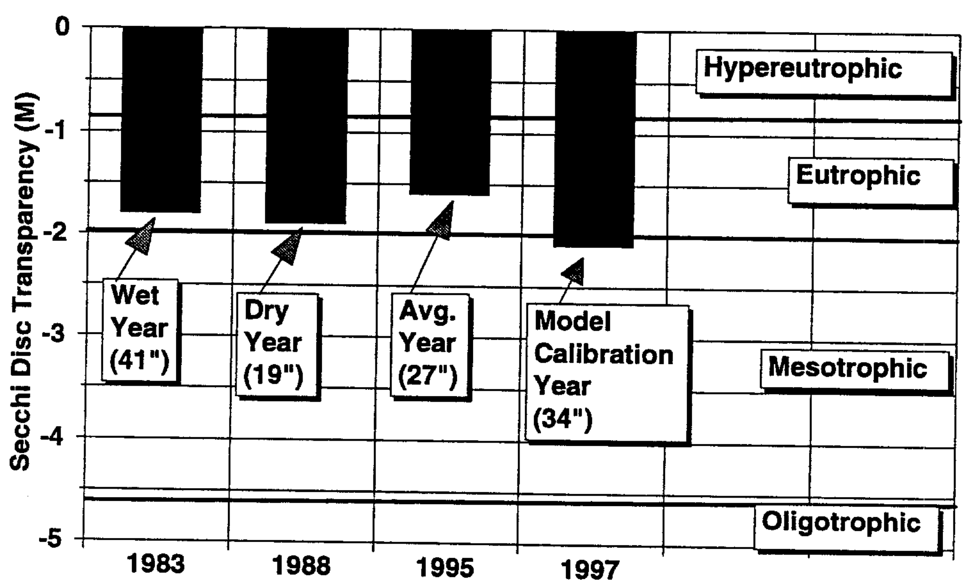

Figure 14b

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2.8 Land Use Assessment

The Lake Lucy and Lake Ann watersheds are currently only partially developed. Increased residential and commercial development are both planned in these watersheds (Figure 2). As a part of this use attainability study management practices to prevent phosphorus loading increases were evaluated. Upgrade and addition of wet detention ponds, and addition of infiltration basins in areas of new development were found to significantly reduce phosphorus loads to Lake Lucy and Lake Ann. Therefore, these practices should be required of future developments to prevent degradation of the lakes' water quality.

3.0 Lake Lucy and Lake Ann Goals

The approved water management plan of the Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) articulated five specific goals for Lake Lucy and Lake Ann. These goals address water quality, recreation, aquatic communities, water quantity, and wildlife. Graphs showing detailed information on the goal achievement of the BMPs discussed in this report can be found in Appendix F. A discussion of the goals follows.

3.1 Water Quality Goals

3.1.1 Lake Lucy

The water quality goal is a Trophic State Index score of 57 or lower, reflecting the RPBCWD policy of non-degradation of current lake water quality conditions. This goal is attainable, but only with recommended BMPs throughout the Lake Lucy watershed.

Four different alternatives will achieve or exceed the District goal water quality goal for Lake Lucy. Figure 15 compares costs of the four alternatives and Table 13 compares water quality benefits of the alternatives under varying climatic conditions. The four alternatives are:

- WQ_{Lucy}-1—Preserve (All) (Preserve all existing wetlands in the Lake Lucy watershed)
- WQ_{Lucy}-2— Preserve (All), Upgrade (1) (Upgrade Wetland in LU-A3.4), Add (1) (Add pond in LU-A1.10).
- WQ_{Lucy}-3— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14).
- WQ_{Lucy}-4— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy Watershed).

3.1.2 Lake Ann

The water quality goal is a Trophic State Index score of 49 or lower, reflecting the RPBCWD policy of non-degradation of current lake water quality conditions. This goal is attainable, but only with recommended BMPs throughout the Lake Ann and Lake Lucy watersheds.

Table 13: Benefits of Water Quality Management Alternatives for Lake Lucy

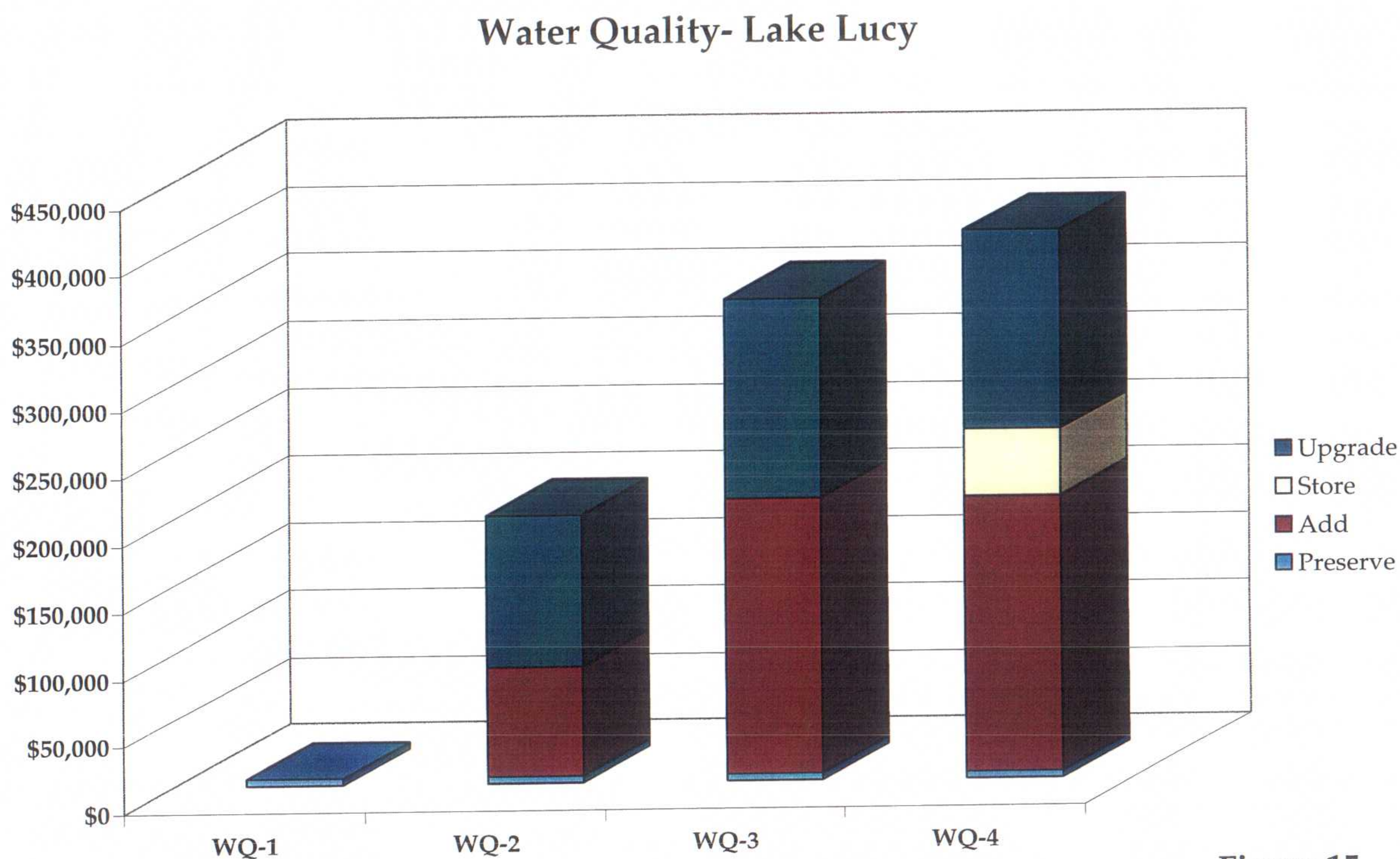
Alternative	Trophic State Index (TSI) Value				
	District Goal	Wet Year (1983; 41 inches of precipitation)	Model Calibration (1997; 34 inches of precipitation)	Average Year (1995; 27 inches of precipitation)	Dry Year (1988; 19 inches of precipitation)
WQ_{Lucy}-1: Preserve (All)	<= 57	58*	55	57	57
WQ_{Lucy}-2: Preserve (All) Upgrade (1), Add (1)	<= 57	57	54	56	57
WQ_{Lucy}-3: Preserve (All) Upgrade (2), Add (7)	<= 57	57	54	55	56
WQ_{Lucy}-4: Preserve (All) Upgrade (2), Add (7), Store	<= 57	55	52	53	55

* Does not meet the District's Water Quality Goal.

Table 14: Benefits of Water Quality Management Alternatives for Lake Ann

Alternative	Trophic State Index (TSI) Value				
	District Goal	Wet Year (1983; 41 inches of precipitation)	Model Calibration (1997; 34 inches of precipitation)	Average Year (1995; 27 inches of precipitation)	Dry Year (1988; 19 inches of precipitation)
WQ_{Ann}-1: Preserve (All) Upgrade (2), Add (12)	<= 49	49	47	50*	49
WQ_{Ann}-2: Preserve (All) Upgrade (2), Add (12), Store	<= 49	48	46	49	46

* Does not meet the District's Water Quality Goal.



The cost of wetland aquisition is not included in costs for these alternatives. If voluntary or required wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

Figure 15

Two different alternatives will achieve or exceed the District goal water quality goal for Lake Lucy. Figure 16 compares costs of the two alternatives and Table 14 compares water quality benefits of the alternatives under varying climatic conditions. The two alternatives are:

- **WQ_{Ann}-1**— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (12) (Add ponds in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9).

- **WQ_{Ann}-1**— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (12) (Add ponds in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds).

3.2 Recreation Goal

3.2.1 Lake Lucy

The recreation goal for Lake Lucy is to achieve full support of fishing activities and maintain waterfowl habitat. As discussed in Section 3.3 of this report, "Aquatic Communities Goal", this goal can be considered a non-degradation goal as fishing in Lake Lucy is currently considered satisfactory.

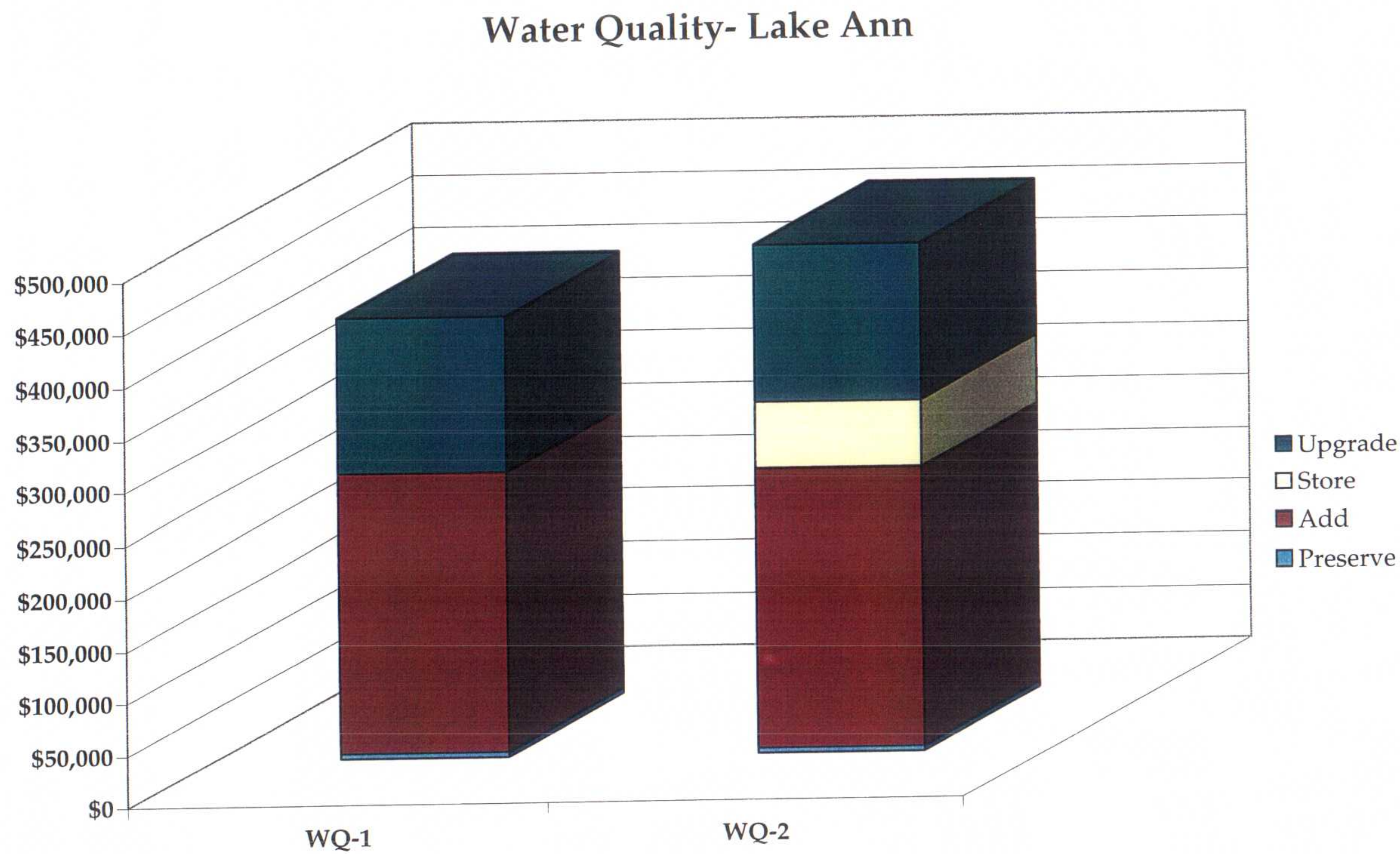
The goal can be achieved through the implementation of watershed management practices. Five different alternatives will achieve or exceed the District water quality goal. Figure 17 compares costs of the five alternatives and Table 15 compares water quality benefits of the alternatives under varying climatic conditions. The five alternatives are:

- **REC_{Lucy}-1**—Preserve (All) (Preserve all existing wetlands in the Lake Lucy watershed)

- **REC_{Lucy}-2**— Preserve (All), Upgrade (1) (Upgrade Wetland in LU-A3.4), Add (1) (Add pond in LU-A1.10).

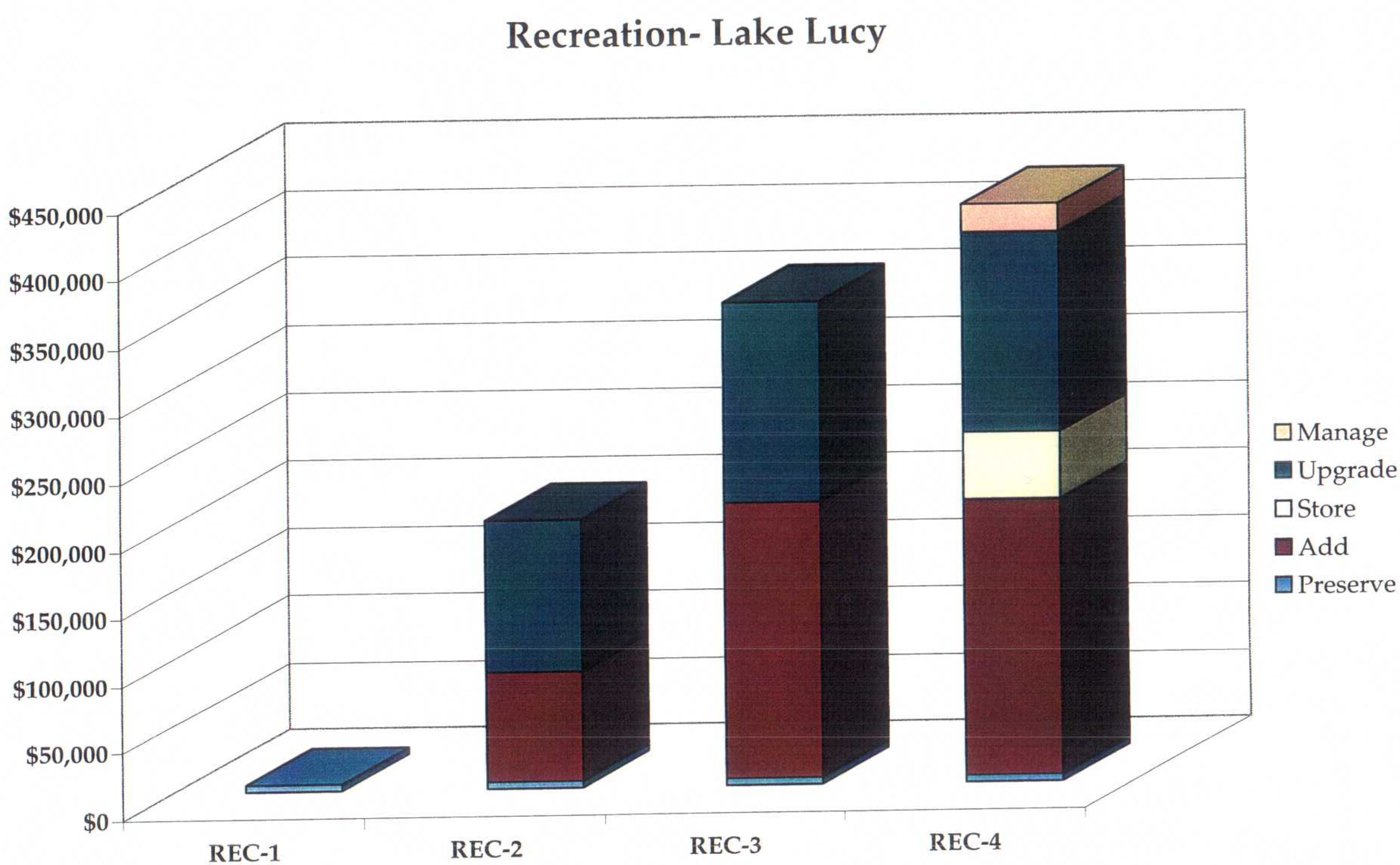
- **REC_{Lucy}-3**— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14).

- **REC_{Lucy}-4**— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy Watershed).



The cost of wetland aquisition is not included in costs for these alternatives. If voluntary or required wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

Figure 16



The cost of wetland aquisition is not included in costs for these alternatives. If voluntary or required wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

Figure 17

REC$_{Lucy}$-5— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy Watershed) and Manage (Stock sport fish when necessary after winterkills, hire commercial anglers to remove bullheads and construct a fishing pier on the lake to facilitate better fishing for the public).

3.2.2 Lake Ann

The recreation goal for Lake Ann is to achieve a fully supporting use support classification in accord with the "MPCA Use Support Classification for Swimming Relative to Carlson's Trophic State Index by Ecoregion," (MPCA, 1997) with a Trophic State Index of less than or equal to 53. This goal is attainable by recommended BMPs throughout the Lake Ann and Lake Lucy watersheds.

Five different alternatives will achieve or exceed the District water quality goal. Figure 18 compares costs of the five alternatives and Table 16 compares water quality benefits of the five alternatives under varying climatic conditions. The five alternatives are:

- **REC$_{Ann}$-1**—Preserve (All) (Preserve all existing wetlands in the Lake Lucy watershed)
- **REC$_{Ann}$-2**— Preserve (All), Upgrade (1) (Upgrade Wetland in LU-A3.4), Add (1) (Add pond in LU-A1.10).
- **REC$_{Ann}$-3**— Preserve (All), Upgrade (1), Add (6) (Add pond in LU-A1.10, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9)
- **REC$_{Ann}$-4**— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (12) (Add pond in LU-A1.10, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14).
- **REC$_{Ann}$-5**— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy Watershed).

Table 15: Benefits of Recreation Management Alternatives for Lake Lucy

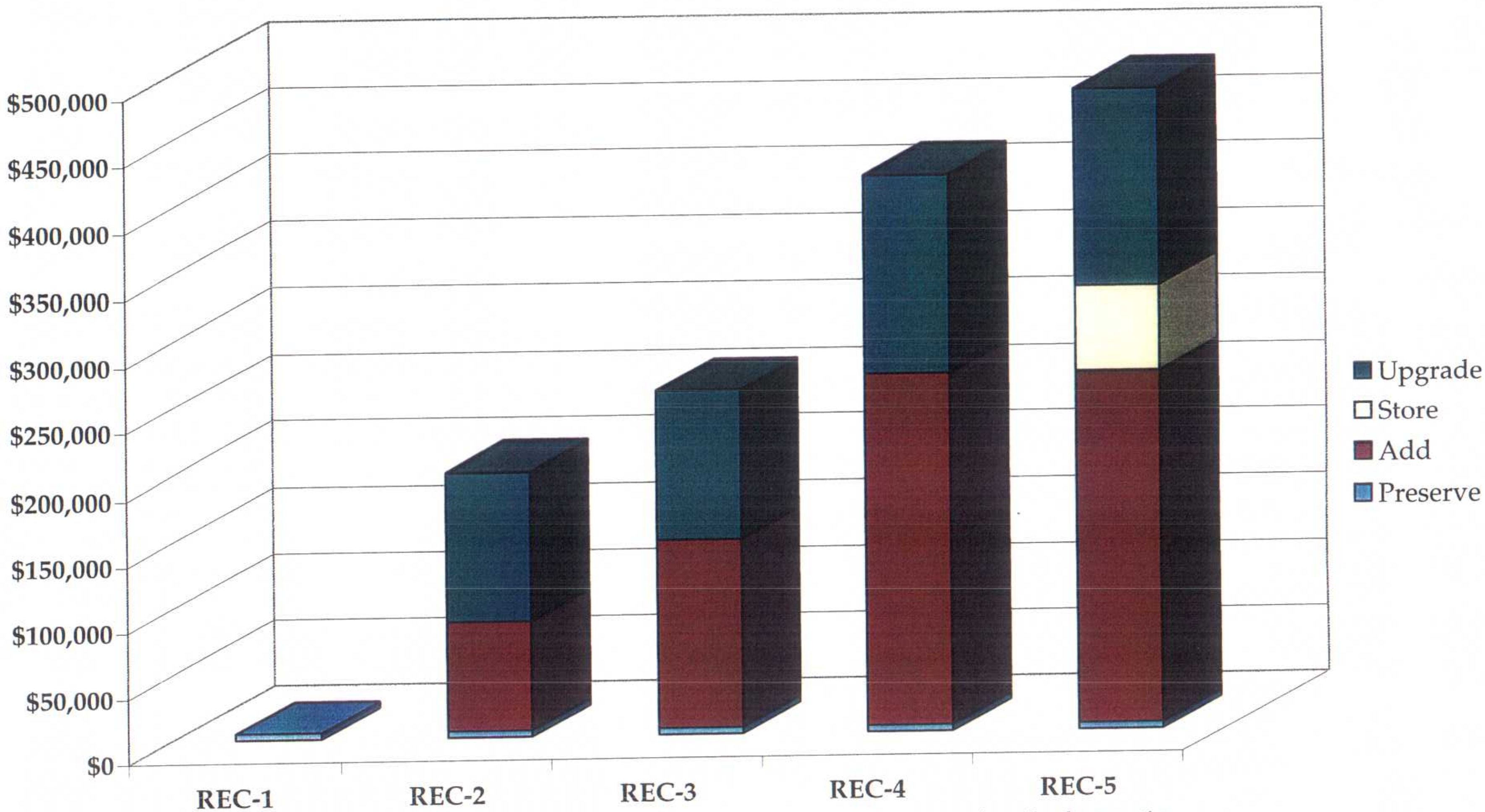
Alternative	Trophic State Index (TSI) Value				
	District Goal	Wet Year (1983; 41 inches of precipitation)	Model Calibration (1997; 34 inches of precipitation)	Average Year (1995; 27 inches of precipitation)	Dry Year (1988; 19 inches of precipitation)
REC_{Lucy}-1: Preserve (All)	<= 57	58*	55	57	57
REC_{Lucy}-2: Preserve (All) Upgrade (1), Add (1)	<= 57	57	54	56	57
REC_{Lucy}-3: Preserve (All) Upgrade (2), Add (7)	<= 57	57	54	55	56
REC_{Lucy}-4: Preserve (All) Upgrade (2), Add (7), Store	<= 57	55	52	53	55
REC_{Lucy}-5: Preserve (All) Upgrade (2), Add (7), Store, Manage**	<= 57	55	52	53	55

* Does not meet the District's Water Quality Goal.
** "Manage" fish stocking after winterkills, rough fish removal and installation of a fishing pier.

Table 16: Benefits of Recreation Management Alternatives for Lake Ann

Alternative	Trophic State Index (TSI) Value				
	District Goal	Wet Year (1983; 41 inches of precipitation)	Model Calibration (1997; 34 inches of precipitation)	Average Year (1995; 27 inches of precipitation)	Dry Year (1988; 19 inches of precipitation)
REC_{Ann}-1: Preserve (All)	<= 53	52	49	53	50
REC_{Ann}-2: Preserve (All) Upgrade (1), Add (1)	<= 53	51	49	52	50
REC_{Ann}-3: Preserve (All) Upgrade (1), Add (6)	<= 53	50	47	51	49
REC_{Ann}-4: Preserve (All) Upgrade (2), Add (12)	<= 53	49	47	50	49
REC_{Ann}-5: Preserve (All) Upgrade (2), Add (12), Store	<= 53	48	46	49	46

Recreation- Lake Ann



The cost of wetland aquisition is not included in costs for these alternatives. If voluntary or required wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

Figure 18

3.3 Aquatic Communities

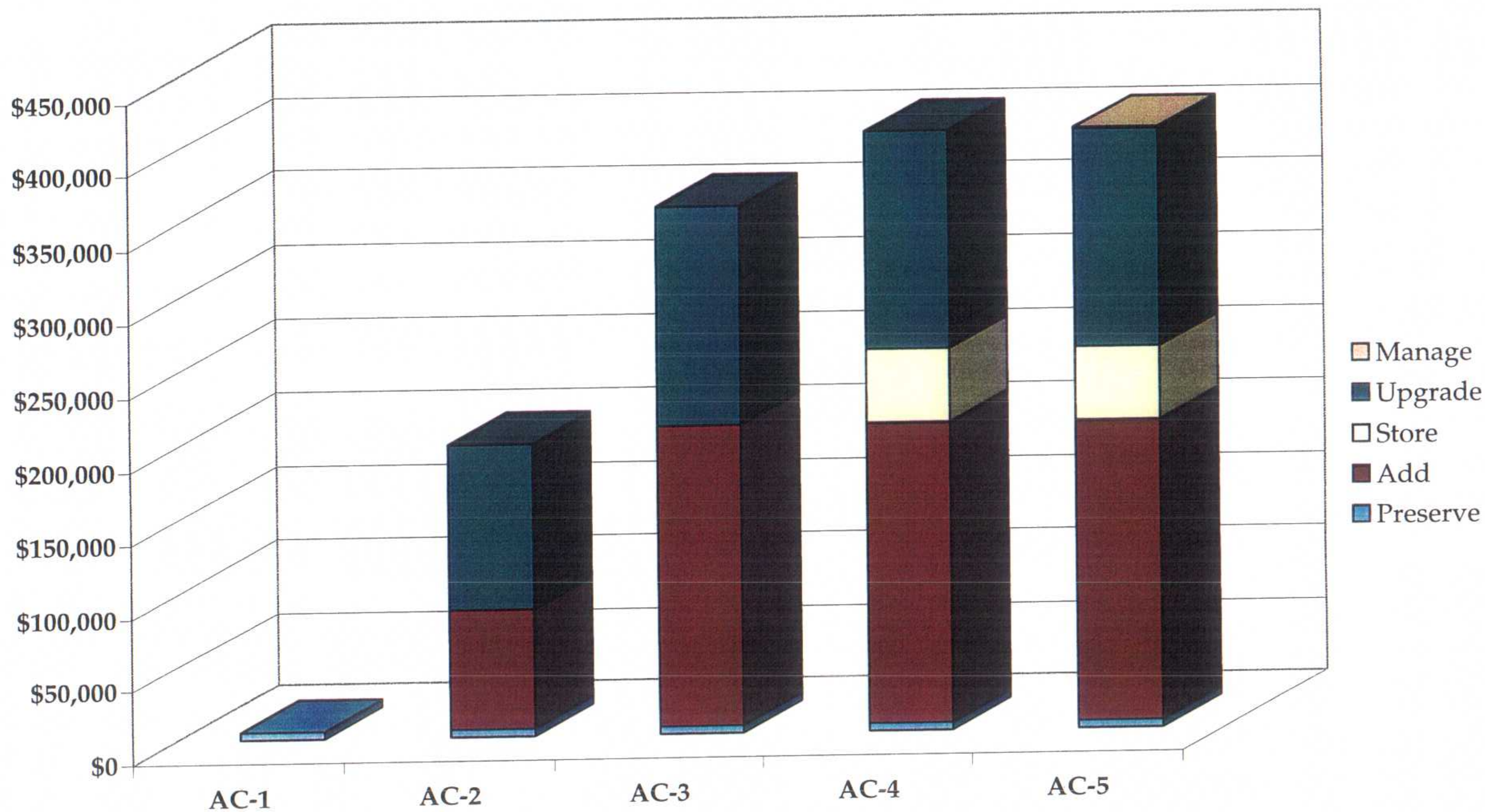
3.3.1 Lake Lucy

The aquatic communities goal for Lake Lucy, as stated in the District's water management plan is "to maintain a MDNR ecological class 42 rating, with a Trophic State Index of 62." Likewise, the aquatic communities goal for Lake Ann is stated as, "...to maintain a MDNR ecological Class 24 rating, with a Trophic State Index of approximately 56." It would take a large change in water clarity to move a lake into a different lake class (Schupp, 1999). Therefore, this part of the goal can be achieved with no action. A TSI of 62 corresponds to the average Secchi disc transparency of the class 42 lakes studied in by the MDNR (0.9 m). A TSI of 56 corresponds to a Secchi disc transparency of 1.3 m, the average of the class 24 lakes studied by the MDNR. Because Lake Lucy and Lake Ann currently have summer average Secchi Disc transparencies greater than these averages (1.3 m and 3.2 m, respectively), and because the water quality goal for both of these lakes is based on a non-degradation policy, it seems that a more reasonable aquatic communities goal for these lakes would also involve non-degradation of the existing aquatic communities (as measured by water quality).

With this type of goal for Lake Lucy, five different alternatives will achieve or exceed the aquatic communities goal . Figure 19 compares costs of the five alternatives and Table 17 compares water quality benefits of the alternatives under varying climatic conditions. The five alternatives are:

- AC-1_{Lucy}— Preserve (All) (Preserve all existing wetlands in the Lake Lucy watershed)
- AC-2_{Lucy}— Preserve (All), Upgrade (1) (Upgrade Wetland in LU-A3.4), Add (1) (Add pond in LU-A1.10).
- AC-3_{Lucy}— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14).
- AC-4_{Lucy}— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy Watershed).

Aquatic Communities- Lake Lucy



The cost of wetland aquisition is not included in costs for these alternatives. If voluntary or required wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

Figure 19

AC-5_{Lucy}— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (7) (Add pond in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy Watershed) and Manage (Continue macrophyte surveys on Lake Lucy to ensure a diverse community).

3.3.2 Lake Ann

With this type of goal for Lake Ann, three different alternatives will achieve or exceed the aquatic communities goal. Figure 20 compares costs of the three alternatives and Table 18 compares water quality benefits of the alternatives under varying climatic conditions. The three alternatives are:

- AC-1_{Ann}— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (12) (Add ponds in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9).

- AC-2_{Ann}— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (12) (Add ponds in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds).

- AC-3_{Ann}— Preserve (All), Upgrade (2) (Upgrade Wetland in LU-A3.4 and pond in LU-A5.2), Add (12) (Add ponds in LU-A1.10, LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14, LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9), Store (Store Stormwater in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds) and Manage (Continue macrophyte surveys on Lake Ann to ensure a diverse community).

3.4 Water Quantity Goal

The Water Quantity Goal for both Lake Lucy and Lake Ann is to provide sufficient water storage during a regional flood. This goal is attainable with no action.

3.5 Wildlife Goal

The wildlife goal for Lake Lucy and Lake Ann is to protect existing, beneficial wildlife uses. The wildlife goal can be achieved with no action, especially if the wetlands and park land surrounding the lakes in the City of Chanhassen's future land use plan stays intact.

Table 17: Benefits of Aquatic Communities Management Alternatives for Lake Lucy

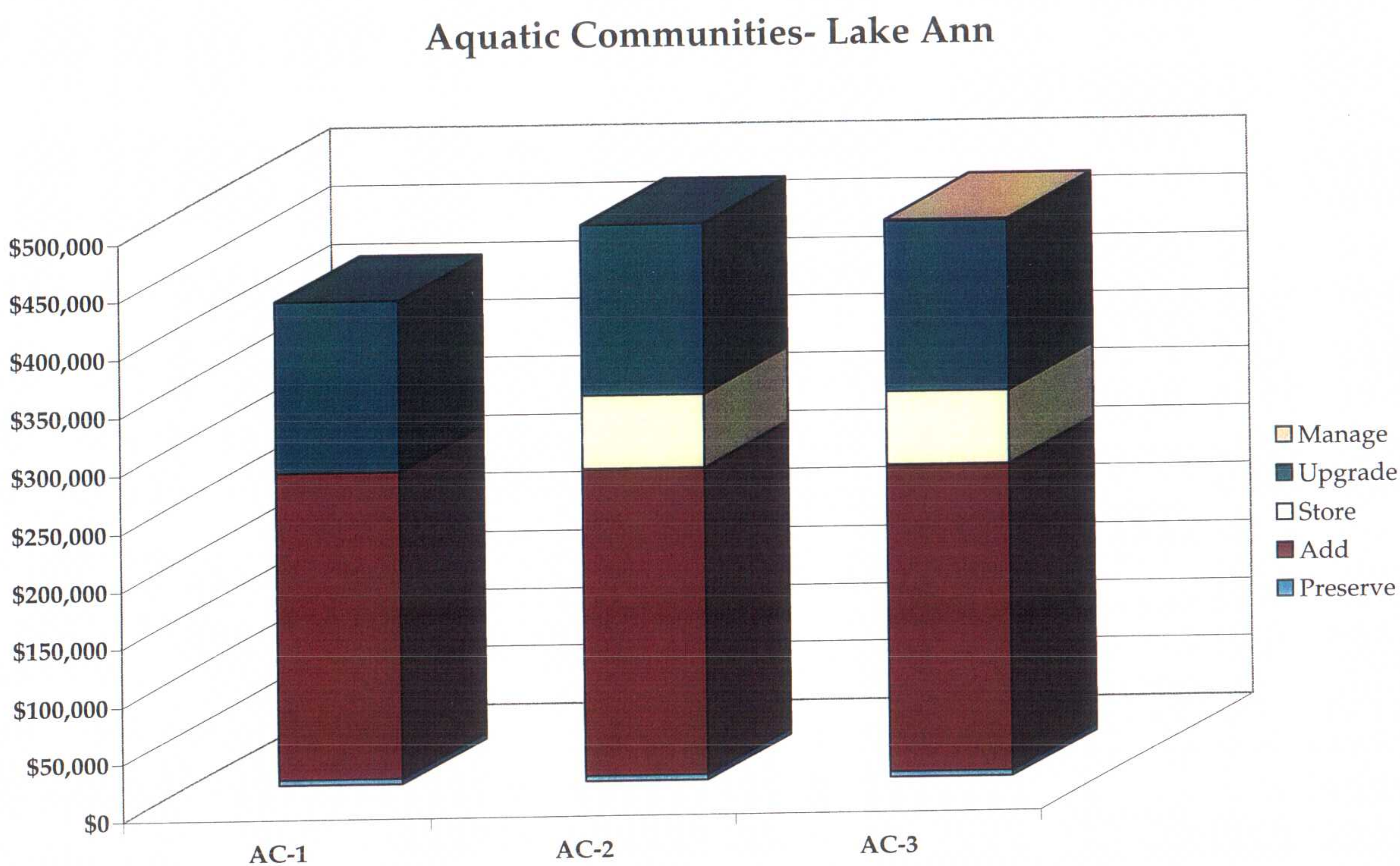
Alternative	Trophic State Index (TSI) Value				
	District Goal	Wet Year (1983; 41 inches of precipitation)	Model Calibration (1997; 34 inches of precipitation)	Average Year (1995; 27 inches of precipitation)	Dry Year (1988; 19 inches of precipitation)
AC_{Lucy}-1: Preserve (All)	<= 57	58*	55	57	57
AC_{Lucy}-2: Preserve (All) Upgrade (1), Add (1)	<= 57	57	54	56	57
AC_{Lucy}-3: Preserve (All) Upgrade (2), Add (7)	<= 57	57	54	55	56
AC_{Lucy}-4: Preserve (All) Upgrade (2), Add (7), Store	<= 57	55	52	53	55
AC_{Lucy}-5: Preserve (All) Upgrade (2), Add (7), Store, Manage**	<= 57	55	52	53	55

* Does not meet the District's Water Quality Goal.
** "Manage" includes continued macrophyte surveys of Lake Lucy.

Table 18: Benefits of Aquatic Communities Management Alternatives for Lake Ann

Alternative	Trophic State Index (TSI) Value				
	District Goal	Wet Year (1983; 41 inches of precipitation)	Model Calibration (1997; 34 inches of precipitation)	Average Year (1995; 27 inches of precipitation)	Dry Year (1988; 19 inches of precipitation)
AC_{Ann}-1: Preserve (All) Upgrade (2), Add (12)	<= 49	49	47	50*	49
AC_{Ann}-2: Preserve (All) Upgrade (2), Add (12), Store	<= 49	48	46	49	46
AC_{Ann}-3: Preserve (All) Upgrade (2), Add (12), Store, Manage**	<= 49	48	46	49	46

* Does not meet the District's Water Quality Goal.
**"Manage" includes continued macrophyte surveys of Lake Ann.



The cost of wetland aquisition is not included in costs for these alternatives. If voluntary or required wetland protections are not likely to succeed, the estimated cost of obtaining these areas for preservation would be at current market value.

Figure 20

3.6 Public Participation

The public participation goal is to encourage public participation as a part of the use attainability analysis. This goal will be achieved through a public meeting to obtain comments on the use attainability analysis.

Barr Engineering Company. 1973a. 1971-1972 Water Quality Inventory. Prepared for Riley-Purgatory Creek Watershed District.

Barr Engineering Company. 1973b. 1972 Engineer's Annual Report. Prepared for Riley-Purgatory Creek Watershed District.

Barr Engineering Company. 1976. 1975 Engineer's Annual Report. Prepared for Riley-Purgatory Creek Watershed District.

Barr Engineering Company. 1982. 1981 Lake Quality Inventory Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Red Rock, Rice Marsh, Riley, Round, Staring, and Susan. Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 1985. 1984 Lake Quality Inventory Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Red Rock, Rice Marsh, Riley, Round, Staring, and Susan. Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 1989. 1988 Lake Water Quality Inventory: Lakes Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Red Rock, Rice Marsh, Riley, Round, Staring, and Susan. Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 1993. 1990 and 1991 Lake Water Quality Inventory and Historical Water Quality Trend Analysis Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Red Rock, Rice Marsh, Riley, Round, Staring, and Susan. Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 1996a. 1993 and 1994 Lake Water Quality Inventory, Trend Analysis, and Mass Balance Modeling: Lakes Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Red Rock, Rice Marsh, Riley, Round, Staring, and Susan. Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 1996b. Water Management Plan, May 1996. Prepared for Riley-Purgatory-Bluff Creek Watershed.

Bonestroo, Rosene, Anderlik and Associates, 1994 City of Chanhassen Surface Water Management Plan. Prepared for the City of Chanhassen.

Carlson, R. E. 1977. A Trophic State Index for Lakes. Limnology and Oceanography 22 (2): 361-369.

Dillon, P. J. and F. H. Rigler. 1974. A Test of a Simple Nutrient Budget Model Predicting the Phosphorus Concentrations in Lake Water. J. Fish. Res. Bd. Can. 31: 1771-1778.

Ellison, Darryl. 1999. Minnesota Department of Natural Resources Area Fisheries Manager, personal communication.

Heiskary, S. A. and C. B. Wilson. 1990. Minnesota Lake Water Quality Assessment Report Second Edition A Practical Guide for Lake Managers. Minnesota Pollution Control Agency.

Hoffman, Todd. 1999. Chanhassen Parks Director, personal communication.

IEP, Inc. 1990. P8 Urban Catchment Model. Version 2.1. Prepared for the Narragansett Bay Project. Providence, Rhode Island.

Minnesota Department of Natural Resources. 1995. Annual Fisheries Survey Report—Lake Lucy.

Minnesota Department of Natural Resources. 1995. Annual Fisheries Survey Report—Lake Ann.

Minnesota Pollution Control Agency (MPCA). 1989. Protecting Water Quality in Urban Areas.

Minnesota Pollution Control Agency. 1997. Lake Prioritization for Protecting Swimmable Use: Part of a series on Minnesota Lake Water Quality Assessment.

Nurnberg, G.K. 1998. Prediction of annual and seasonal phosphorus concentrations in stratified and polymictic lakes. Limnology & Oceanography 43(7): 1544-1552.

Schupp, D. H. 1992. An Ecological Classification of Minnesota Lakes With Associated Fish Communities. Investigational Report 417, Minnesota Department of Natural Resources.

Schupp, Dennis. 1999. Brainerd DNR, personal communications.

Walker, W.W. 1987. Phosphorus Removal by Urban Runoff Detention Basins. Lake and Reservoir Management: Volume III. North American Lake Management Society.

Appendices

Appendix A

Lake Lucy and Lake Ann 1996-1997 Water Quality Data

Lake Lucy

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
04/21/97	6.4	1.4	0-2	22.3	--	--	--	0.047	0.003	2.22	8.3
			0.0		14.2	10.5	484				
			1.0		15.1	9.5	483				
			2.0		15.0	8.5	478				
			3.0		14.5	8.0	481	0.036			8.3
			4.0		12.0	8.0	482	0.049			8.2
			5.0		10.6	6.0	482	0.063			8.1
			6.0		6.8	5.5	486	0.060			8.0

Lake Lucy

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
06/17/97	6.4	2.3	0-2	9.1	--	--	--	0.035	0.002	0.91	8.0
			0.0		9.2	22.0	503				
			1.0		9.1	22.0	503				
			2.0		9.1	22.0	503				
			3.0		7.5	20.0	522	0.033			7.9
			4.0		3.5	16.5	529	0.027			7.7
			5.0		0.5	15.0	536	0.078			7.4
			6.0		0.2	13.0	549	0.197			7.2

Lake Lucy

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
07/14/97	6.4	0.9	0-2	40.4	--	--	--	0.044	0	1.16	8.7
			0.0		11.1	24.5	439				
			1.0		11.0	24.0	444				
			2.0		11.0	24.0	447				
			3.0		0.8	20.0	482	0.053			8.7
			4.0		0.6	19.0	490	0.084			8.0
			5.0		0.1	17.5	504	0.159			7.7
			6.0		0.1	16.5	529	0.269			7.5

Lake Lucy

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
08/05/97	6.4	0.8	0-2	31.8	--	--	--	0.076	0.007	1.50	8.1
			0.0		7.2	26.5	446				
			1.0		7.2	26.0	446				
			2.0		5.5	25.5	465				
			3.0		0.3	21.0	481	0.124			7.5
			4.0		0.1	18.5	497	0.242			7.4
			5.0		0.1	17.0	513	0.316			7.4
			6.0		0.1	16.5	523	0.455			7.4

Lake Lucy

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
08/18/97	6.4	1.2	0-2	29.8	--	--	--	0.061	<0.010	1.33	7.6
			0.0		4.8	21.0	465				
			1.0		4.6	21.0	465				
			2.0		4.3	21.0	465				
			3.0		3.0	21.0	470	0.081			7.6
			4.0		0.5	19.0	504	0.288			7.5
			5.0		0.5	17.5	518	0.562			7.4
			6.0		0.5	16.5	530	0.842			7.2

Lake Lucy

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
09/02/97	6.4	1.4	0-2	11.3	--	--	--	0.055	<0.010	1.17	7.9
			0.0		7.6	23.5	459				
			1.0		7.2	23.0	464				
			2.0		4.4	22.5	468				
			3.0		1.5	20.0	484	0.074			7.6
			4.0		0.4	19.0	522	0.144			7.5
			5.0		0.3	17.5	516	0.431			7.3
			6.0		0.2	16.5	540	0.621			7.3

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
10/14/96	12.1	1.4	0-2	20.0	--	--	--	0.037	<0.010	1.18	7.4
			0.0		7.8	13.0	292				
			1.0		7.8	13.0	311				
			2.0		7.6	13.0	318				
			3.0		6.8	13.0	324	0.031			7.3
			4.0		6.5	13.0	328	0.031			7.3
			5.0		6.3	13.0	330	0.026			7.3
			6.0		6.2	13.0	336	0.026			7.3
			7.0		6.1	13.0	340	0.029			7.3
			8.0		5.7	13.0	340	0.031			7.3
			9.0		4.1	12.5	347	0.037			7.3
			10.0		3.9	12.5	347	0.060			7.2
			11.0		1.8	9.0	375	0.342			6.7
			11.6		1.2	8.5	386	0.722			6.6

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
12/26/96	11.5	3.5	0-2	2.0	--	--	--	0.039	<0.010	1.38	9.5
			0.0		10.4	1.5	386				
			1.0		10.4	1.5	395				
			2.0		9.8	2.0	390				
			3.0		9.0	2.3	385	0.022			8.7
			4.0		8.3	2.5	394	0.024			8.4
			5.0		6.5	2.5	397	0.030			8.2
			6.0		5.2	3.0	397	0.037			8.0
			7.0		4.0	3.0	405	0.045			7.9
			8.0		2.8	3.0	407	0.062			7.8
			9.0		1.8	3.0	413	0.083			7.7
			10.0		0.5	3.5	408	0.105			7.6
			11.0		0.4	3.5	408	0.122			7.5

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
03/05/97	12.1	2.1	0-2	0.9	--	--	--	0.036	0.016	1.52	7.7
			0.0		6.5	0.5	413				
			1.0		6.2	1.5	420				
			2.0		6.2	2.0	418				
			3.0		5.8	3.0	410	0.036			7.4
			4.0		5.0	3.0	413	0.038			7.3
			5.0		4.1	3.0	421	0.051			7.3
			6.0		1.8	3.0	423	0.074			7.3
			7.0		1.2	3.5	424	0.129			7.0
			8.0		1.2	3.5	432	0.174			6.9
			9.0		1.0	3.5	435	0.167			6.9
			10.0		0.5	3.5	448	0.192			6.9
			11.0		0.5	3.5	464	0.189			6.9
			11.6		0.2	3.5	467	0.199			6.9

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
04/21/97	12.1	1.4	0-2	30.3	--	--	--	0.061	0.003	2.65	7.7
			0.0		13.4	9.0	377				
			1.0		13.4	9.0	377				
			2.0		12.0	6.5	398				
			3.0		11.2	6.0	393	0.040			7.9
			4.0		10.5	5.5	398	0.036			7.9
			5.0		10.2	5.5	395	0.035			7.9
			6.0		9.9	5.5	395	0.033			7.8
			7.0		9.8	5.0	400	0.031			7.8
			8.0		9.6	5.0	400	0.033			7.8
			9.0		9.5	5.0	400	0.024			7.8
			10.0		9.5	5.0	400	0.029			7.8
			11.0		9.4	5.0	400	0.033			7.8
			11.6		9.3	5.0	400	0.038			7.8

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
05/05/97	12.1	1.3	0-2	20.8	--	--	--	0.048	0.001	2.46	8.8
			0.0		15.8	12.5	374				
			1.0		15.8	12.5	373				
			2.0		15.8	12.5	375				
			3.0		15.8	12.0	381	0.039			8.8
			4.0		15.6	12.0	380	0.036			8.8
			5.0		8.6	8.5	406	0.053			8.5
			6.0		7.2	6.5	397	0.042			7.8
			7.0		6.9	6.0	398	0.036			7.4
			8.0		5.3	5.5	397	0.034			7.2
			9.0		5.1	5.0	400	0.031			7.1
			10.0		5.0	5.0	400	0.059			7.1
			11.0		4.0	5.0	405	0.027			7.2
			11.6		3.8	5.0	413	0.027			7.3

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
05/19/97	12.1	2.1	0-2	4.4	--	--	--	0.023	0	1.11	8.6
			0.0		10.5	13.0	394				
			1.0		10.4	13.0	394				
			2.0		10.5	13.0	394				
			3.0		10.4	13.0	394	0.048			8.5
			4.0		8.7	11.5	408	0.048			8.6
			5.0		7.6	11.0	412	0.053			8.6
			6.0		5.5	10.0	405	0.059			8.4
			7.0		4.3	9.5	410	0.034			8.2
			8.0		1.1	7.5	425	0.038			7.8
			9.0		0.2	6.5	432	0.02			7.6
			10.0		0.2	6.0	435	0.016			7.6
			11.0		0.2	6.0	447	0.013			7.6
			11.6		0.2	6.0	447	0.011			7.6

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
06/02/97	12.1	5.0	0-2	2.1	--	--	--	0.027	0	1.07	8.2
			0.0		8.6	19.5	411				
			1.0		8.6	19.5	411				
			2.0		8.4	16.0	410				
			3.0		8.4	15.5	402	0.035			8.2
			4.0		8.2	15.0	400	0.029			8.2
			5.0		6.6	14.0	408	0.029			8.1
			6.0		0.8	11.5	419	0.035			7.9
			7.0		0.5	9.0	421	0.056			7.5
			8.0		0.2	7.0	431	0.058			7.3
			9.0		0.2	7.0	422	0.044			7.2
			10.0		0.2	6.5	422	0.052			7.1
			11.0		0.2	6.5	422	0.052			7.1
			11.6		0.2	6.5	422	0.056			7.1

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
07/02/97	12.1	2.7	0-2	4	--	--	--	0.019	0	0.86	7.7
			0.0		8.5	23.5	386				
			1.0		8.5	23.5	386				
			2.0		8.5	23.5	386				
			3.0		8.5	23.5	386	0.015			7.7
			4.0		8.5	23.5	386	0.023			7.7
			5.0		6.2	16	416	0.023			7.6
			6.0		0.5	12.5	430	0.027			7.1
			7.0		0.5	10.0	443	0.042			6.9
			8.0		0.2	8.5	428	0.063			6.8
			9.0		0.2	8.0	427	0.064			6.8
			10.0		0.2	8.0	427	0.068			6.8
			11.0		0.2	8.0	427	0.072			6.8
			11.6		0.2	8.0	427	0.083			6.8

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
07/14/97	12.1	2.9	0-2	6.8	--	--	--	0.017	0	0.87	8.6
			0.0		9.2	24	377				
			1.0		9.3	24	377				
			2.0		9.4	24	377				
			3.0		9.5	24	377	0.017			8.6
			4.0		8.6	21	400	0.019			8.6
			5.0		4.1	17.5	408	0.024			8.3
			6.0		0.2	12.5	430	0.026			8.1
			7.0		0.1	10.5	424	0.048			7.9
			8.0		0.1	10.0	423	0.063			7.6
			9.0		0.1	9.5	424	0.071			7.5
			10.0		0.1	9.0	428	0.084			7.4
			11.0		0.1	8.5	428	0.088			7.4
			11.6		0.1	8.5	428	0.086			7.4

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
08/05/97	13.0	3.2	0-2	5.2	--	--	--	0.048	0.003	0.95	8.7
			0.0		8.4	26.0	372				
			1.0		8.5	26.0	372				
			2.0		8.4	26.0	372				
			3.0		8.4	26.0	372	0.044			8.7
			4.0		7.0	24.0	386	0.053			8.5
			5.0		1.2	19.0	409	0.049			8.4
			6.0		0.4	15.0	420	0.051			8.5
			7.0		0.3	11.5	427	0.087			8.0
			8.0		0.2	10.0	435	0.094			7.5
			9.0		0.2	9.5	433	0.115			7.3
			10.0		0.2	9.5	433	0.117			7.3
			11.0		0.2	9.5	433	0.111			7.3
			12.0		0.2	9.5	429	0.131			7.2
			12.5		0.2	9.5	429	0.145			7.2

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
08/18/97	12.7	2.3	0-2	10.6	--	--	--	0.022	<0.010	1.00	8.0
			0.0		6.3	22.0	376				
			1.0		6.3	22.0	377				
			2.0		61.0	22.0	377				
			3.0		6.1	22.0	382	0.017			8.2
			4.0		6.0	22.0	382	0.02			8.3
			5.0		1.2	19.5	405	0.024			7.9
			6.0		0.4	15.5	420	0.088			7.8
			7.0		0.2	12.0	429	0.084			7.6
			8.0		0.2	10.5	433	0.07			7.3
			9.0		0.2	10.0	435	0.115			7.3
			10.0		0.2	9.5	440	0.15			7.2
			11.0		0.2	9.5	440	0.183			7.2
			12.2		0.2	9.0	440	0.188			7.2

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
09/02/97	12.1	2.7	0-2	6.2	--	--	--	0.023	<0.010	0.96	8.6
			0.0		8.6	24.0	375				
			1.0		8.5	24.0	375				
			2.0		8.3	24.0	375				
			3.0		8.8	22.0	390	0.025			8.6
			4.0		1.5	20.0	399	0.03			8.6
			5.0		0.9	17.0	418	0.032			8.1
			6.0		0.3	13.0	455	0.091			7.8
			7.0		0.2	10.0	465	0.081			7.7
			8.0		0.2	9.5	468	0.129			7.6
			9.0		0.2	9.5	454	0.181			7.4
			10.0		0.2	9.0	456	0.187			7.3
			11.0		0.2	9.0	456	0.191			7.3
			11.6		0.2	9.0	456	0.244			7.3

Lake Ann

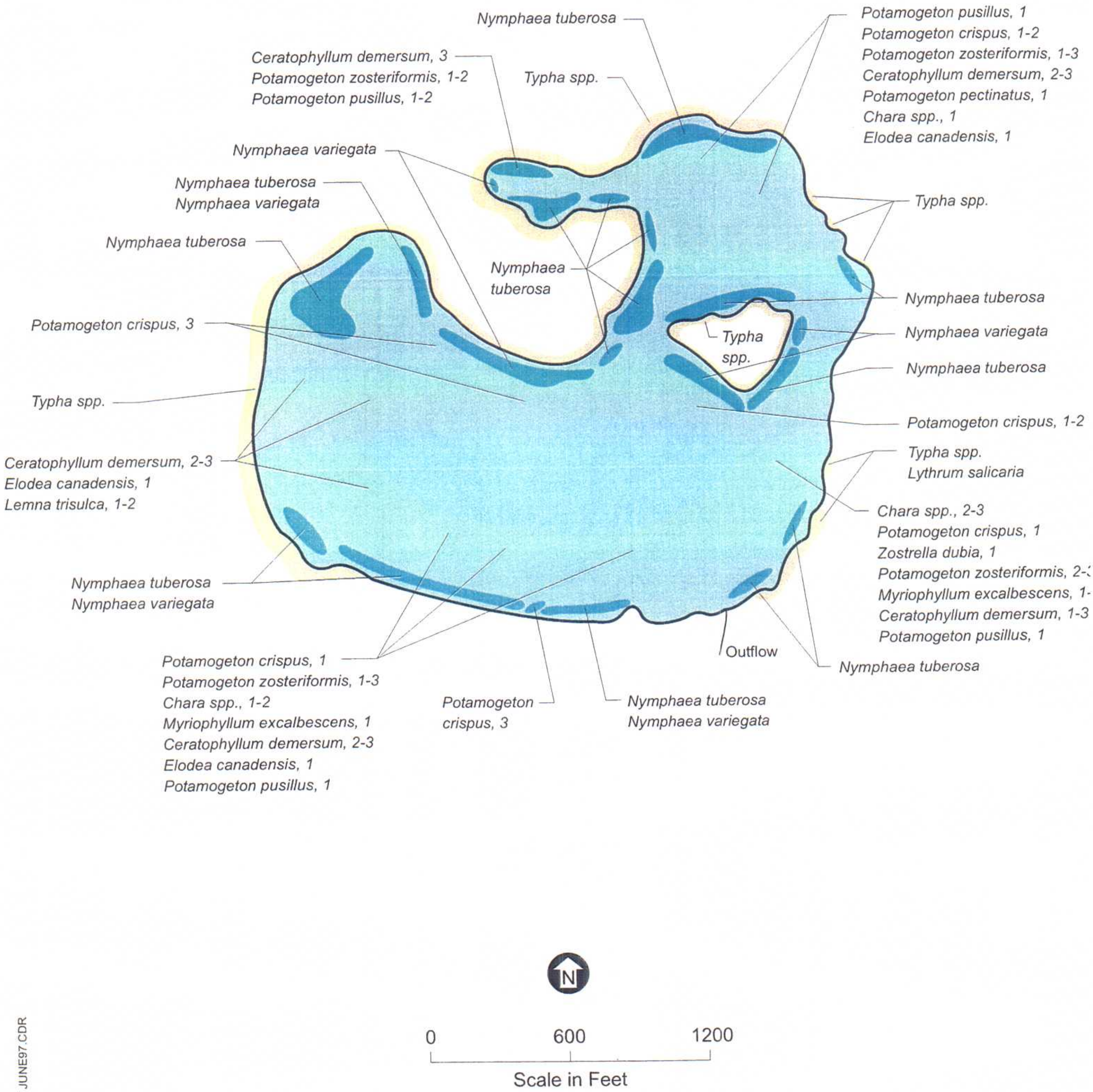
Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
09/17/97	12.1	2.4	0-2	6.6	--	--	--	0.025	<0.010	1.00	7.8
			0.0		7.8	21.0	367				
			1.0		7.8	21.0	367				
			2.0		7.8	21.0	367				
			3.0		7.8	21.0	367	0.023			7.9
			4.0		7.7	21.0	367	0.017			8.0
			5.0		7.7	21.0	367	0.017			8.0
			6.0		2.0	16.0	405	0.049			7.4
			7.0		1.0	14.5	416	0.118			7.2
			8.0		0.6	11.0	452	0.138			7.0
			9.0		0.6	10.0	447	0.196			6.9
			10.0		0.3	9.5	447	0.271			6.9
			11.0		0.2	9.5	447	0.352			6.8
			11.6		0.2	9.0	452	0.362			6.8

Lake Ann

Date	Max. Depth (M)	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P (mg/L)	Total N (mg/L)	pH (Std. Units)
10/14/97	12.7	1.7	0-2	9.5	--	--	--	0.043	<0.010	1.14	7.7
			0.0		6.5	14.5	380				
			1.0		6.4	14.5	380				
			2.0		6.4	14.5	380				
			3.0		6.4	14.5	380	0.037			7.7
			4.0		6.4	14.5	380	0.043			7.7
			5.0		6.4	14.5	380	0.039			7.8
			6.0		6.3	14.5	380	0.037			7.8
			7.0		6.3	14.5	381	0.035			7.8
			8.0		6.3	14.5	382	0.037			7.8
			9.0		6.3	14.5	382	0.039			7.8
			10.0		4.6	13.0	396	0.039			7.8
			11.0		0.5	9.5	433	0.078			7.7
			12.2		0.5	9.0	460	0.235			7.3

Appendix B

Lake Lucy and Lake Ann 1996-1997 Biological Data



P:2327053/LAKEMAPS/LUCY/1997 JUNE97.CDR

LAKE LUCY
June 19, 1997

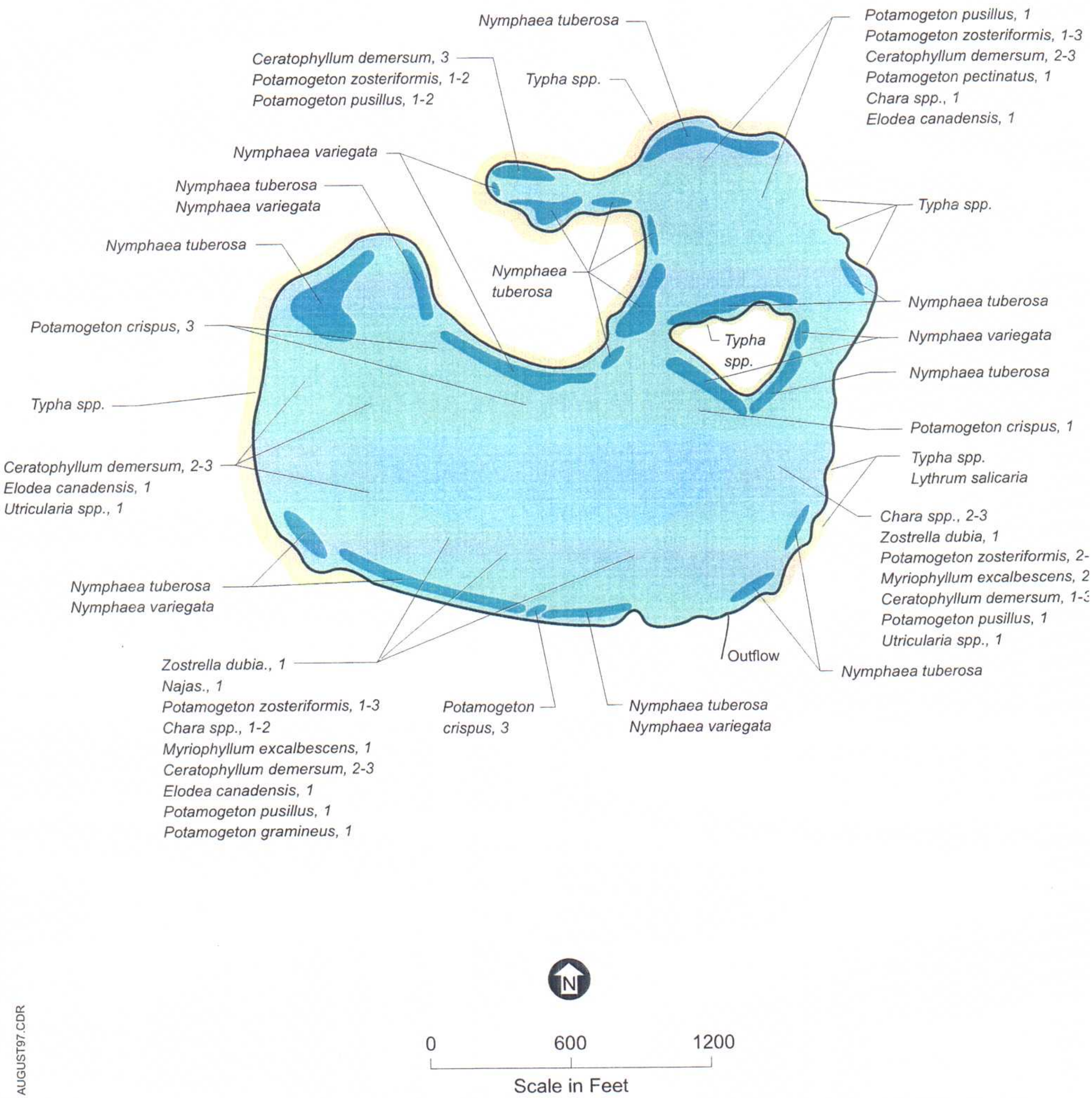
LAKE LUCY MACROPHYTE SURVEY
June 19, 1997

- No macrophytes found in water > 10 feet
- Macrophyte densities estimated as follows: 1=light; 2=moderate; 3= heavy

	Common Name	Scientific Name
Submerged Aquatic Plants:	Pondweed	*Potamogeton pusillus*
	Curly leaf pondweed	*Potamogeton crispus*
	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Coontail	*Ceratophyllum demersum*
	Elodea	*Elodea canadensis*
	Muskgrass	*Chara spp.*
	Northern watermilfoil	*Myriophyllum excalbescens*
	Water star grass	*Zostrella dubia*
	Star duck weed	*Lemna trisulca*
Floating Leaf:	White waterlily	*Nymphaea tuberosa*
	Yellow waterlily	*Nymphaea variegata*
	Floating leaf pond	*Potamogeton natans*
Emergent:	Cattail	*Typha spp.*
	Purple loosestrife	*Lythrum salicaria*
No Aquatic Vegetation Found:		

Comments:

P:2327053/LAKEMAPS/LUCY/1997/MACJUN97.CDR



LAKE LUCY
August 21, 1997

P:2327053/LAKEMAPS/LUCY/1997 AUGUST97.CDR

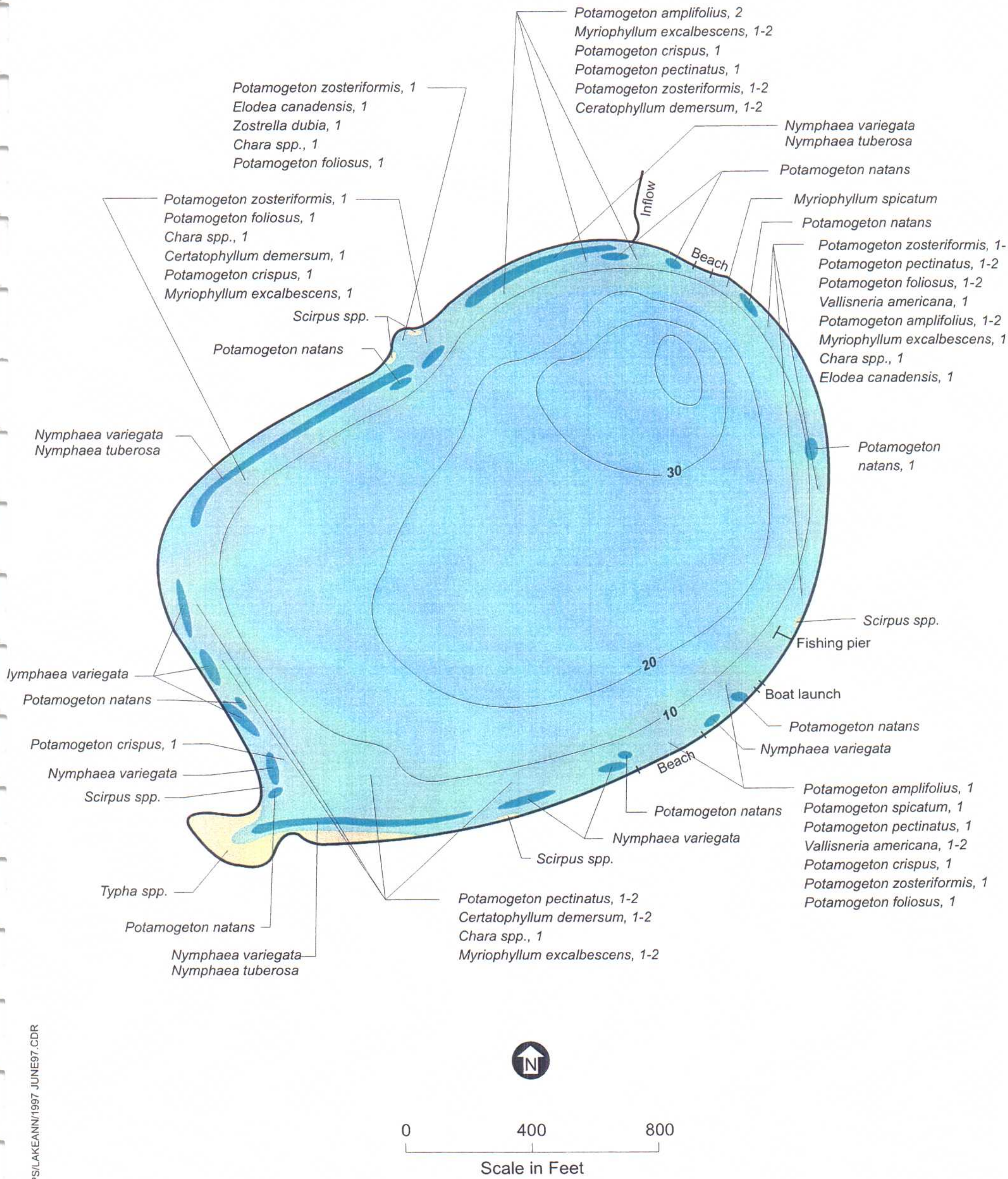
LAKE LUCY MACROPHYTE SURVEY
August 21, 1997

- No macrophytes found in water > 10 feet
- Macrophyte densities estimated as follows: 1=light; 2=moderate; 3= heavy

	Common Name	Scientific Name
Submerged Aquatic Plants:	Variable pondweed	*Potamogeton gramineus*
	Pondweed	*Potamogeton pusillus*
	Curly leaf pondweed	*Potamogeton crispus*
	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Coontail	*Ceratophyllum demersum*
	Elodea	*Elodea canadensis*
	Muskgrass	*Chara spp.*
	Bushy pondweed and naiads	*Najas spp.*
	Northern watermilfoil	*Myriophyllum excalbescens*
	Water star grass	*Zostrella dubia*
	Bladdwurt	*Utricularia spp.*
Floating Leaf:	White waterlily	*Nymphaea tuberosa*
	Yellow waterlily	*Nymphaea variegata*
	Floating leaf pond	*Potamogeton natans*
Emergent:	Cattail	*Typha spp.*
	Purple loosestrife	*Lythrum salicaria*
No Aquatic Vegetation Found:		

Comments: Lythrum salicaria present along shoreline of entire lake. (Light in density)

P:2327053/LAKEMAPS/LUCY/1997/MACAUG97.CDR



P:2327878/LAKEMAPS/LAKEANN/1997 JUNE97.CDR

LAKE ANN
June 19, 1997

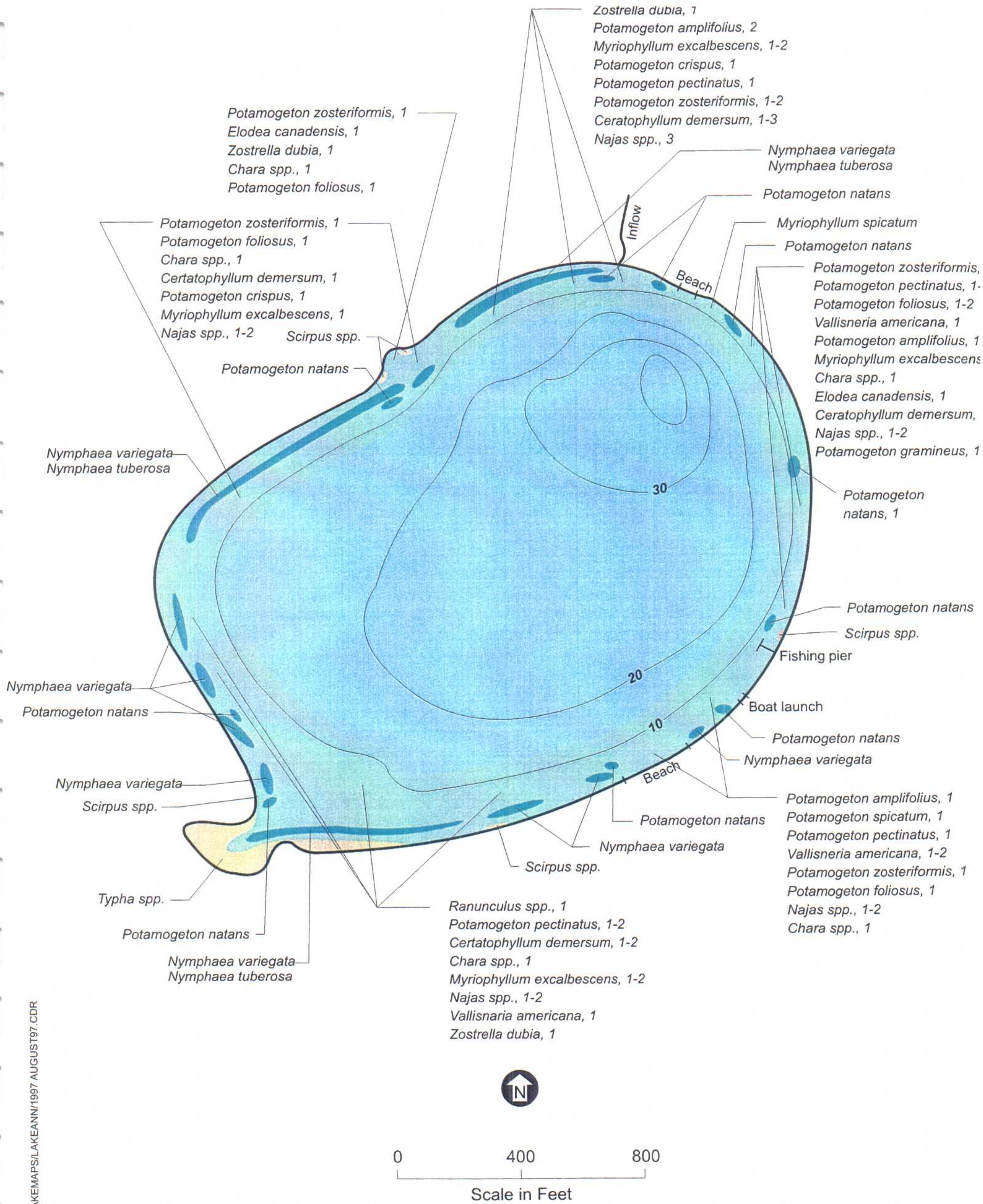
LAKE ANN MACROPHYTE SURVEY
June 19, 1997

- No macrophytes found in water > 9-11 feet
- Macrophyte densities estimated as follows: 1=light; 2=moderate; 3= heavy

	Common Name	Scientific Name
Submerged Aquatic Plants:	Large leaf pondweed	*Potamogeton amplifolius*
	Curly leaf pondweed	*Potamogeton crispus*
	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Leafy pondweed	*Potamogeton foliosus*
	Eurasian watermilfoil	*Myriophyllum spicatum*
	Coontail	*Ceratophyllum demersum*
	Water celery	*Vallisneria americana*
	Elodea	*Elodea canadensis*
	Muskgrass	*Chara spp.*
	Northern watermilfoil	*Myriophyllum excalbescens*
	Water star grass	*Zostrella dubia*
Floating Leaf:	Floating leaf pondweed	*Potamogeton natans*
	White waterlily	*Nymphaea tuberosa*
	Yellow waterlily	*Nymphaea variegata*
Emergent:	Bulrush	*Scirpus spp.*
	Cattail	*Typha spp.*
No Aquatic Vegetation Found:		

Comments:

P:2327051/LAKEMAPS/BASSETTS/LAKEANN/1997/MACJUN97.CDR



P:2327878/LAKEMAPS/LAKEANN/1997 AUGUST97.CDR

LAKE ANN
August 21, 1997

LAKE ANN MACROPHYTE SURVEY
August 21, 1997

- No macrophytes found in water > 9-11 feet
- Macrophyte densities estimated as follows: 1=light; 2=moderate; 3= heavy

	Common Name	Scientific Name
Submerged Aquatic Plants:	Buttercup	*Ranunculus spp.*
	Variable pondweed	*Potamogeton gramineus*
	Large leaf pondweed	*Potamogeton amplifolius*
	Curly leaf pondweed	*Potamogeton crispus*
	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Leafy pondweed	*Potamogeton foliosus*
	Eurasian watermilfoil	*Myriophyllum spicatum*
	Coontail	*Ceratophyllum demersum*
	Water celery	*Vallisneria americana*
	Elodea	*Elodea canadensis*
	Muskgrass	*Chara spp.*
	Northern watermilfoil	*Myriophyllum excalbescens*
	Water star grass	*Zostrella dubia*
Floating Leaf:	Floating leaf pondweed	*Potamogeton natans*
	White waterlily	*Nymphaea tuberosa*
	Yellow waterlily	*Nymphaea variegata*
Emergent:	Bulrush	*Scirpus spp.*
	Cattail	*Typha spp.*
No Aquatic Vegetation Found:		

Comments: Lythrum salcaria observed along northern shoreline.

P:2327051/LAKEMAPS/BASSETTS/LAKEANN/1997/MACAUG97.CDR

LAKE LUCY

SAMPLE: 0-2 METERS (INT. TUBE)
STANDARD INVERTED MICROSCOPE ANALYSIS METHOD

DIVISION	TAXON	04/21/97 units/mL	06/17/97 units/mL	07/14/97 units/mL	08/05/97 units/mL	08/18/97 units/mL	09/02/97 units/mL
CHLOROPHYTA (GREEN ALGAE)	*Actinastrum Hantzschii*	0	0	117	898	0	39
	Ankistrodesmus falcatus	78	0	39	0	0	0
	Ankistrodesmus Brauni	0	0	0	0	156	273
	Botryo;coccus sudeticus	0	0	0	0	117	39
	Chlamydomonas globosa	10,941	234	234	1,484	1,835	1,444
	Closterium sp.	0	78	0	586	195	195
	Cosmarium sp.	0	0	0	0	0	0
	Lagerheimia sp.	0	0	0	0	0	0
	Oocystis parva	0	39	0	0	78	156
	Pandorina morum	0	0	0	0	0	0
	Scenedesmus quadricauda	0	0	0	0	312	0
	Scenedesmus sp.	0	0	0	0	0	0
	Schroederia Judayi	547	586	195	117	2,264	117
	Selenastrum minutum	0	0	0	0	0	0
	Sphaerocystis Schroeteri (Colony)	0	156	0	0	117	0
	Selenastrum sp.	0	0	0	0	0	0
	Staurastrum sp.	0	0	39	39	0	0
	Tetraedron minimum	0	0	0	0	0	39
	Tetraedron muticum	0	0	0	0	0	39
	Unidentified Green flagellate	21,335	0	0	0	0	0
	CHLOROPHYTA TOTAL	**32,901**	**1,093**	**625**	**3,123**	**5,075**	**2,342**
CHRYSOPHYTA (GOLDEN BROWN ALGAE)	*Dinobryon sociale*	78	0	0	0	0	78
	CHLOROPHYTA TOTAL	**78**	**0**	**0**	**0**	**0**	**78**
CYANOPHYTA (BLUE-GREEN ALGAE)	*Anabaena affinis*	0	39	468	5,348	1,054	0
	Anabaena flos-aquae	0	195	39	0	0	0
	Anabaenopsis raciborski	0	0	0	0	0	0
	Aphanizomenon flos-aquae	313	78	18,349	10,189	7,847	11,712
	Aphanocapsa delicatissima	0	0	0	0	0	0
	Coelosphaerium Naegelianum	0	0	156	156	312	312
	Lyngbya limnetica	0	0	0	0	0	0
	Merismopedia tenuissima	0	0	0	390	117	0
	Microcystis aeruginosa	0	0	78	0	78	0
	Microcystis incerta	0	0	273	0	0	39
	Oscillatoria Agardhii	0	0	0	0	0	0
	Oscillatoria limnetica	0	0	0	0	0	0
	CYANOPHYTA TOTAL	**313**	**312**	**19,364**	**16,084**	**9,409**	**12,063**
BACILLARIOPHYTA (DIATOMS)	*Amphora ovalis*						
	Asterionella formosa	0	0	0	0	0	0
	Cymbella sp.	0	0	0	0	0	0
	Diatoma sp.	0	0	0	0	0	0
	Fragilaria crotonensis	781	0	0	0	0	0
	Gomhonema sp.	0	0	0	0	0	0
	Melosira granulata	0	0	234	0	0	0
	Navicula sp.	0	0	39	0	0	0
	Stephanodiscus Hantzschii	0	0	0	0	0	0
	Synedra ulna	1,485	0	0	78	0	0
	BACILLARIOPHYTA TOTAL	**2,266**	**0**	**273**	**78**	**0**	**0**
CRYPTOPHYTA (CRYPTOMONADS)	*Cryptomonas erosa*	12,895	1,796	351	1,952	3,318	3,475
	CRYPTOPHYTA TOTAL	**12,895**	**1,796**	**351**	**1,952**	**3,318**	**3,475**
PYRRHOPHYTA (DINOFLAGELLATES)	*Ceratium hirundinella*	0	937	0	0	0	78
	Peridinium cinctum	0	0	0	0	0	0
	PYRRHOPHYTA TOTAL	**0**	**937**	**0**	**0**	**0**	**78**
	TOTALS	**48,375**	**4,138**	**20,613**	**21,238**	**17,802**	**17,958**

LAKE ANN

SAMPLE: 0-2 METERS (INT. TUBE)
STANDARD INVERTED MICROSCOPE ANALYSIS METHOD

DIVISION	TAXON	12/26/96 units/mL	03/05/97 units/mL	04/21 units/mL	05/19 units/mL	06/02 units/mL	07/02 units/mL	07/14 units/mL	08/05 units/mL	08/18 units/mL	09/02 units/mL	09/17 units/mL	10/14 units/mL
CHLOROPHYTA (GREEN ALGAE)	*Ankistrodesmus falcatus*	0	0	527	0	0	0	37	0	0	20	42	0
	Chlamydomonas globosa	569	234	2,570	3,603	126	225	3,935	233	122	111	316	274
	Closteriopsis sp.	0	0	0	0	0	0	0	10	0	0	0	0
	Closterium sp.	0	0	0	0	0	0	0	30	0	30	0	0
	Elakatothrix gelatinosa	0	0	0	0	0	0	0	10	0	0	0	0
	Lagerheimia sp.	0	0	0	0	0	0	0	20	0	0	21	0
	Oocystis parva	0	0	0	0	0	19	19	0	19	0	0	0
	Quadrigula sp.	0	0	0	0	0	0	0	0	0	20	0	0
	Scenedesmus quadricauda	0	0	0	0	0	19	0	0	0	0	0	0
	Schroederia Judayi	42	39	1,268	0	84	75	37	40	47	40	63	21
	Sphaerocystis Schroeteri (Colony)	0	0	0	0	0	0	37	0	0	10	42	0
	Selenastrum minutum	0	0	0	0	0	0	0	10	0	0	0	0
	CHLOROPHYTA TOTAL	611	273	4,365	3,603	211	337	4,066	354	187	233	485	295
CYANOPHYTA (BLUE-GREEN ALGAE)	*Anabaena affinis*	0	0	0	0	0	0	0	192	197	172	169	21
	Anabaena flos-aquae	0	0	0	0	0	0	19	0	28	30	0	0
	Anabaena spiroides v. crassa	0	0	0	0	0	0	0	0	0	0	21	0
	Aphanizomenon flos-aquae	695	0	0	84	0	56	187	718	2,417	1,375	2,107	1,454
	Aphanocapsa delicatissima	0	0	0	0	0	0	37	0	0	0	0	0
	Coelosphaerium Naegelianum	0	0	0	0	0	0	169	0	37	61	126	0
	Lyngbya sp.	0	0	0	0	0	0	0	0	0	10	0	0
	Merismopedia tenuissima	0	0	16	0	0	37	150	0	0	0	21	0
	Merismopedia sp.	0	0	0	0	0	0	0	0	9	0	0	0
	Microcystis aeruginosa	0	0	0	0	42	0	19	0	37	0	0	0
	Microcystis incerta	0	0	0	63	0	693	468	293	309	71	21	0
	Oscillatoria limnetica	0	0	0	0	0	0	0	0	0	71	147	105
	Phormidium mucicola	0	0	0	0	0	0	0	0	0	0	0	63
	CYANOPHYTA TOTAL	695	0	16	147	42	787	1,049	1,204	3,036	1,790	2,613	1,643
BACILLARIOPHYTA (DIATOMS)	*Fragilaria capucina*	0	0	0	0	0	0	0	0	0	0	0	21
	Fragilaria crotensis	0	0	0	190	0	0	0	0	0	0	0	0
	Melosira granulata	0	0	0	0	0	0	206	0	0	0	0	0
	Navicula sp.	0	0	16	21	42	56	19	0	9	0	0	21
	Rhoicosphenia curvata	0	0	0	0	0	19	0	0	0	0	0	0
	Stephanodiscus Hantzschii	0	0	1,993	21	0	0	0	0	9	0	0	0
	Stephanodiscus sp.	0	0	0	126	0	19	75	0	0	0	0	0
	Synedra ulna	0	0	68	1,032	0	0	0	0	19	0	0	0
	BACILLARIOPHYTA TOTAL	0	0	2,076	1,391	42	94	300	0	37	0	0	42
	Cryptomonas erosa	948	605	0	5,352	716	150	581	597	309	1,183	927	1,601
	CRYPTOPHYTA TOTAL	948	605	0	5,352	716	150	581	597	309	1,183	927	1,601
PYRROPHYTA (DINOFLAGELLATES)	*Ceratium hirundinella*	0	0	0	0	0	0	0	10	19	0	21	0
	PYRRHOPHYTA TOTAL	0	0	0	0	0	0	0	10	19	0	21	0
	TOTALS	2,254	878	6,457	10,493	1,011	1,368	5,997	2,164	3,589	3,206	4,045	3,582

LAKE:	Lucy						
SAMPLE DATE:		04/21/97	06/17/97	07/14/97	08/18/97	08/05/97	09/02/97
DIVISION	TAXON	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter
	Daphnia galeata mendotae	0	239,835	2,106	14,034	2,143	17,831
	Diaphanosoma leuchtenbergianum	0	2,351	10,532	23,391	19,288	4,458
	Bosmina sp.	0	21,162	63,192	442,085	40,719	124,816
	Chydorus sp.	0	14,108	12,638	0	0	4,458
	Ceriodaphnia sp.	0	286,861	240,129	152,040	197,168	131,502
	Daphnia parvula	0	0	0	0	0	2,229
	Total Cladocera	0	564,317	328,597	631,550	259,319	285,293
COPEPODA							
	Nauplii	210,419	188,106	82,149	72,511	68,580	82,468
	Cyclops sp.	3,478	7,054	0	0	0	2,229
	Mesocyclops sp.	3,478	35,270	35,809	32,747	25,718	75,781
	Diaptomus sp.	0	72,891	107,426	2,339	38,576	15,602
	Total Copepoda	217,375	303,320	225,384	107,597	132,874	176,080
ROTIFERA							
	Conochilus sp.	0	0	31,596	51,460	19,288	24,517
	Keratella cochlearis	6,956	202,213	56,873	23,391	40,719	28,975
	Polyarthra vulgaris	0	312,726	223,277	11,695	90,011	40,119
	Asplanchna sp.	10,434	7,054	23,170	14,034	2,143	8,915
	Filinia longiseta	0	0	0	0	0	0
	Keratella quadrata	19,129	18,811	0	0	0	0
	Kellicottia sp.	0	2,351	4,213	9,356	0	0
	Trichocerca sp.	0	2,351	0	4,678	38,576	11,144
	Total Rotifera	36,519	545,506	339,129	114,615	190,739	113,672
	TOTAL ZOOPLANKTON	253,894	1,413,143	893,110	853,762	582,931	575,045

1996-1997 Lake Ann Zooplankton Data

LAKE:	Ann												
SAMPLE DATE:		07/02/97	08/05/97	08/18/97	09/02/97	09/17/97	03/05/97	05/05/97	05/19/97	12/26/96	04/21/97	06/02/97	10/14/97
DIVISION	TAXON	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter	#/sq.meter
	Daphnia galeata mendotae	110,218	33,702	23,562	49,353	2,155	4,360	9,307	52,807	127,363	0	216,199	30,886
	Diaphanosoma leuchtenbergianum	0	42,128	10,875	43,659	15,088	0	0	0	0	0	0	0
	Bosmina sp.	0	18,958	19,937	55,048	19,398	0	2,327	4,801	154,305	0	6,687	147,300
	Chydorus sp.	0	0	1,812	11,389	17,243	0	0	0	0	0	4,458	19,006
	Ceriodaphnia sp.	3,674	0	5,437	7,593	0	0	0	0	0	0	6,687	0
	Daphnia retrocurva	0	6,319	12,687	22,778	47,418	0	0	0	0	0	11,144	61,771
	Total Cladocera	113,892	101,107	74,311	189,820	101,303	4,360	11,634	57,607	281,668	0	245,174	258,964
COPEPODA													
	Nauplii	45,924	122,171	284,559	178,431	64,661	23,979	995,882	134,417	17,145	196,188	15,602	111,663
	Cyclops sp.	73,479	8,426	14,500	9,491	6,466	74,116	120,995	811,303	281,668	108,014	1,016,358	90,281
	Mesocyclops sp.	5,511	54,766	57,999	43,659	32,331	0	0	2,400	0	0	4,458	66,523
	Diaptomus sp.	49,598	58,979	32,625	32,269	84,060	39,238	20,941	69,609	46,537	2,204	82,468	68,899
	Total Copepoda	174,512	244,341	389,682	263,850	187,518	137,332	1,137,818	1,017,729	345,350	306,406	1,118,885	337,365
ROTIFERA													
	Conochilus sp.	0	358,086	38,062	56,946	383,657	0	0	0	0	0	0	0
	Keratella cochlearis	11,022	29,489	30,812	45,557	73,283	82,835	253,624	1,039,332	367,394	13,226	3,597,372	772,139
	Polyarthra vulgaris	174,512	69,511	126,873	49,353	99,147	2,180	93,073	189,624	66,131	19,839	120,358	603,456
	Asplanchna sp.	12,859	0	0	1,898	0	0	18,615	24,003	2,449	2,204	6,687	0
	Keratella quadrata	18,370	0	1,812	0	0	2,180	27,922	28,804	22,044	0	86,925	0
	Kellicottia sp.	18,370	14,745	29,000	49,353	28,020	10,899	30,249	43,205	132,262	4,409	167,164	185,313
	Brachionus sp.	0	0	0	0	0	0	0	2,400	0	0	0	0
	Filinia sp.	0	0	0	0	0	0	39,556	14,402	7,348	4,409	0	0
	Trichocerca sp.	0	10,532	1,812	7,593	4,311	0	0	2,400	0	0	0	2,376
	Total Rotifera	235,132	482,363	228,372	210,700	588,418	98,094	463,039	1,344,171	597,627	44,087	3,978,506	1,563,28[illegible]
	TOTAL ZOOPLANKTON	523,536	827,811	692,366	664,370	877,238	239,786	1,612,491	2,419,508	1,224,646	350,494	5,342,565	2,159,614

Appendix C

Methods

The Lake Lucy and Lake Ann use attainability analysis (UAA) included the collection and analysis of data from the lakes and their watersheds. The methods discussion includes:

- Lake water quality data collection
- Ecosystem data collection
- Modeling of watershed stormwater and total phosphorus loadings
- In-lake water quality model

C.1 Lake Water Quality Data Collection

In 1996, representative sampling stations in Lake Lucy and Lake Ann were selected (i.e., located at the deepest location in the lake basins). Lake Ann samples were collected monthly during October and December, 1996 and during March and April, 1997. Samples were collected biweekly during May through September and monthly during October of 1997. Lake Lucy samples were collected monthly during April, June, July and September of 1997 and biweekly in August 1997. A total of nine water quality parameters were measured at the Lake Lucy and Lake Ann sampling stations. Table C-1 lists the water quality parameters and specifies at what depths samples or measurements were collected. Dissolved oxygen, temperature, specific conductance, and Secchi disc transparency were measured in the field; whereas water samples were analyzed in the laboratory for total phosphorus, soluble reactive phosphorus, total nitrogen, chlorophyll *a*, and pH. The procedures for chemical analyses of the water samples are shown in Table C-2. Generally, the methods for these procedures can be found in Standard Methods for Water and Wastewater Analysis.

C.2 Ecosystem Data Collection

The term "ecosystem" describes the community of living things within Lake Lucy and Lake Ann and their interaction with their environment and with each other. During the period December 26, 1996 through October 14, 1997, ecosystem data collection included:

Table C-1 Lake Lucy and Lake Ann Water Quality Parameters

Parameters	Depth (Meters)	Sampled or Measured During Each Sample Event
Dissolved Oxygen	Surface to bottom profile	X
Temperature	Surface to bottom profile	X
Specific Conductance	Surface to bottom profile	X
Secchi Disc	–	X
Total Phosphorus	0-2 Meter Composite Sample	X
Total Phosphorus	Profile at 1 meter intervals from 3 meters to 0.5 meters above the bottom	X
Soluble Reactive Phosphorus	0-2 Meter Composite Sample	X
Total Nitrogen	0-2 Meter Composite Sample	X
pH	0-2 Meter Composite Sample	X
pH	Profile at one meter intervals from 3 meters to 0.5 meters above the bottom	X
Chlorophyll *a*	0-2 Meter Composite Sample	X

Table C-2 Procedures for Chemical Analyses Performed on Water Samples

Analysis	Procedure	Reference
Total Phosphorus	Persulfate digestion, manual ascorbic acid	Standard Methods, 18th Edition (1992) modified per Eisenreich, et al., Environmental Letters 9(1), 43-53 (1975)
Soluble Reactive Phosphorus	Manual ascorbic acid	Standard Methods, 18th Edition modified per Eisenreich, et al., Environmental Letters 9(1), 43-53 (1975)
Total Nitrogen	Persulfate digestion, scanning spectrophotometric	Bachman, Roger W. and Daniel E. Canfield, Jr., 1991. A Comparability Study of a New Method for Measuring Total Nitrogen in Florida Waters. Report submitted to the Florida Department of Environmental Regulation.
Chlorophyll *a*	Spectrophotometric	Standard Methods, 18th Edition, 1992, 10200 H
pH	Potentiometric measurement, glass electrode	Standard Methods, 16th Edition, 1985, 423
Specific Conductance	Wheatstone bridge	Standard Methods, 16th Edition, 1985, 205
Temperature	Thermometric	Standard Methods, 16th Edition, 1985, 212
Dissolved Oxygen	Electrode	Standard Methods, 16th Edition, 1985, 421F
Phytoplankton Identification and Enumeration	Inverted Microscope	Standard Methods, 16th Edition, 1985, 1002F (2-d), 1002H (2)
Zooplankton Identification and Enumeration	Sedgewick Rafter	Standard Methods, 16th Edition, 1985, 1002F (2-d), 1002H
Transparency	Secchi disc	

- Phytoplankton—A composite 0-2 meter sample was collected during each water quality sample event described in the previous section.

- Zooplankton—A zooplankton sample was collected (i.e., bottom to surface tow) during each water quality sample event described in the previous section.

- Macrophytes—Macrophyte surveys were completed during June and August, 1997.

Phytoplankton and zooplankton samples were identified and enumerated to provide information on species diversity and abundance. The macrophyte community was surveyed to determine species locations, composition, and abundance.

C.3 Watershed Stormwater and Total Phosphorus Loadings

The computer model P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds, IEP, Inc., 1990) was used to estimate both the water and phosphorus loads introduced from the entire watershed of Lake Lucy and Lake Ann. The model was used instead of the XP-SWMM model (discussed in the District Water Management Plan) because it is a better predictor of phosphorus loading, the primary focus of the Lake Lucy and Lake Ann UAA. P8 is a useful diagnostic tool for evaluating and designing watershed improvements and best management practices (BMPs).

The model requires hourly precipitation and temperature data; long-term climatic data can be used so that watersheds and BMPs can be evaluated for varying hydrologic conditions. Hourly precipitation data was obtained from a gage located near T.H. 212 and I-494 during the spring, summer, and fall months. Specifically, data were obtained during the period October 1 through November 24, 1996 and from March 13 through September 30, 1997. Hourly precipitation data during the period November 25, 1996 through March 12, 1997 was obtained from the National Weather Service (NWS) site at the Minneapolis–St. Paul International Airport. Snowfall data from the Minneapolis–St. Paul International Airport during the January through March period was modified (i.e., water equivalent reduced from 1.81 inches to 1.61 inches) to match predicted and measured snowmelt runoff water volumes at Sample Stations I-1 and I-2. Precipitation during the July 21, 1997 and August 19, 1997 precipitation events were modified (i.e., reduced by 44 percent and 27 percent, respectively) to match predicted and measured runoff at Round Lake sample stations I-1 and I-2. Hourly temperature data was obtained from the NWS site at the Minneapolis-St. Paul International Airport.

When evaluating the results of the modeling, it is important to consider that the results are more accurate in terms of relative differences than in absolute results. The model will predict the percent difference in phosphorus reduction between various BMP options in the watershed fairly accurately. It also provides a realistic estimate of the relative differences in phosphorus and water loadings from the various subwatersheds and major inflow points to the lake. However, since runoff quality is highly variable with time and location, the phosphorus loadings estimated by the model for a specific watershed may not necessarily reflect the actual loadings, in absolute terms. Various site-specific factors, such as lawn care practices, illicit point discharges and erosion due to construction are not accounted for in the model. The model provides values that are considered typical of the region, given each watershed's respective land uses.

C.3.1 Water Quality Model (P8) Calibration

C.3.1.1 Stormwater Volume Calibration

There were no stormwater inflow points monitored as a part of this study. Therefore, the stormwater loads to the lakes could not be compared against actual water loads measured in 1997. However, water loads were checked by comparing lake levels (based on P8 water load output) and 1997 observed lake levels, with the WATBUD model.

C.3.1.2 Phosphorus Loading Calibration

Because the Round Lake P8 model was calibrated using the stormwater monitoring data collected during the 1997 water year, the same calibrated parameters were used in the Lake Lucy and Lake Ann models. It is believed that the P8 model under-predicted snowmelt loads because of its assumption that model ponds never freeze and therefore can treat runoff year-round. Because snowmelt runoff generally begins when ponds are frozen, treatment is generally reduced. Consequently, a calibration factor (a multiplier of ~2) was used to adjust snowmelt modeled loads to match observed snowmelt loads from ponds discharging to Round Lake. The same adjustment was applied to snowmelt loads in Lake Lucy and Lake Ann.

C.3.1.3 Atmospheric Deposition

An atmospheric wet and dry deposition rate of 0.56 kg/ha/yr. (Tetra Tech. 1982) was applied to the surface area of Lake Lucy and Lake Ann to determine annual phosphorus loading. An annual total phosphorus load from atmospheric deposition of 42 pounds (18.8 kg) was estimated for Lake Lucy and 58 pounds (26.1 kg) was estimated for Lake Ann.

C.4 In-Lake Water Quality Model

C.4.1 Calibration of In-Lake Model to Existing Water Quality

Water quality sample data from 1997 was used to determine the best in-lake water quality model to use for the analysis. The best fit for both lakes proved to be Dillon and Rigler's equation (Dillon and Rigler, 1974) with Nurnberg's retention term (Nurnberg, 1998):

$$SummerTP = L_{ext} * \frac{(1-R)}{q_s}$$

where L_{ext} = area external TP load (in mg/m^2/yr)

R = Nurnberg's retention term

$$= \frac{15}{(18+q_s)}$$

q_s = lake overflow rate (outflow rate/lake area) (in m^2/yr)

While this equation, supplied with 1997 TP loadings as predicted by the P8 model under existing land use conditions, adequately predicted the average TP concentration in Lake Lucy and Lake Ann throughout most of the summer, peak concentrations in late summer were not accounted for. It was assumed, after analyzing historical data from these lakes, that this peak was due to internal loading of TP from the lakes themselves. The above equation was then altered to reflect the influence of internal loading on the summer average in-lake TP concentration in the lakes:

$$SummerTP = L_{ext} * \frac{(1-R)}{q_s} + \frac{1}{5} * \left(\frac{\alpha * L_{int}}{V} \right)$$

where α = 0.6: the fraction of internally-loaded TP assumed available to the algae

L_{int} = the internal TP load (in kg) as estimated from mass balance calculations using historical data from Lake Lucy and Lake Ann

V = lake volume (in m^3)

Note: The second part of the equation is multiplied by 1/5 to reflect the fact that the influence of internal loading was only observed in ~20% of the monitoring data.

This modified equation was tested with other water years as well: 1988, 1990 and 1994. The model predicted in-lake TP concentrations in Lake Lucy and Lake Ann within acceptable levels during these years. After this step, the model was considered to be calibrated.

C.4.2 In-Lake Modeling to Estimate Water Quality During Wet, Dry, and Average Precipitation Years Under Existing Conditions

The calibrated lake water quality mass balance model was then used to estimate Lake Lucy and Lake Ann water quality during wet, average, and dry precipitation conditions. The mean summer total phosphorus concentration within Lake Lucy and Lake Ann was compared during a wet year (i.e., water year 1983, 40.99 inches), dry year (water year 1988, 18.67 inches), and an average year (water year 1995, 26.52 inches). During these years, the total watershed TP load was the sum of P8 model watershed runoff phosphorus contribution for each water year with adjusted snowmelt loading and the estimated inputs from atmospheric deposition. Outflow from the lakes during these years was estimated from the WATBUD model using daily flows predicted by the P8 model and observed lake levels, and lake volume was estimated from lake levels.

C.4.3 In-Lake Modeling to Estimate Water Quality During Wet, Dry, and Average Precipitation Years Under Proposed BMP Conditions

The calibrated water quality mass balance model was used to estimate Lake Lucy and Lake Ann water quality during wet (i.e., 1983 water year), dry (1988 water year), average (1995 water year), and model calibration (i.e., 1997 water year) precipitation conditions under various proposed BMP conditions. The procedures discussed in the previous section were used to determine the modeling components (L_{ext}, q_s, R, V).

C.4.4 Water Quality Modeling to Estimate Chlorophyll *a* and Secchi Disc Values and TSI_{SD}

Chlorophyll *a* and Secchi disc values for Lake Lucy and Lake Ann were estimated from relationships developed by the MPCA from a regression analysis of data collected from phosphorus-limited

Minnesota lakes (MPCA, 1990). The water quality models used to estimate chlorophyll *a* and Secchi disc values are:

$$\text{Log10 Chl } a = 1.16 \text{ Log10 TP} - 0.76$$

$$\text{Log10 Secchi} = -0.57 \text{ Log10 Chl } a + 0.87$$

Where:

TP = measured or estimated epilimnetic (mixed surface layer) mean summer total phosphorus concentration

Chl *a* = estimated epilimnetic (mixed surface layer) mean summer total phosphorus concentration

Secchi = estimated mean summer Secchi disc transparency

TSI_{SD} = was estimated from Carlson (1977):

$$TSI_{SD} = 10 \left(6 - \frac{\text{InSD}}{\in 2} \right)$$

Chlorophyll *a*, Secchi disc, and TSI_{SD} values were estimated during the model calibration (1997 water year), wet (1983 water year), dry (1988 water year), and average (1995 water year) years under existing and various proposed BMP conditions.

Appendix D

P8 Model Parameter Selection

P8 Model Parameter Selection

There was no monitoring of stormwater inflows for Lake Lucy and Lake Ann; this limited the amount of P8 calibration that could be performed. However, because primary data were collected for the Round Lake use attainability analysis, model calibration afforded the opportunity to select P8 parameters that resulted in a good fit between modeled and observed data. Because Round Lake is located near Lake Lucy and Lake Ann and because it lies in the same major drainage system, calibrated parameters from the Round Lake study were used in the Lake Lucy and Lake Ann P8 modeling effort.

The parameters selected for the Round Lake P8 model are discussed in the following paragraphs. P8 parameters not discussed in the following paragraphs were left at the default setting. P8 version 2.1 was used for the modeling.

- Time Step, Snowmelt, & Runoff Parameters (Case-Edit-Other)

- Time Steps Per Hour (Integer)— 6. Selection was based upon the number of time steps required to eliminate continuity errors greater than 2%.

- Minimum Inter-Event Time (Hours)— 10. During 1997 frequent storms were noted during the summer, particularly during July. The selection of this parameter was based upon an evaluation of storm hydrographs to determine which storms should be combined and which storms should be separated to accurately depict runoff from the lake's watershed. It should be noted that the average minimum inter-event time for the Minneapolis area is 6 hours. In a more typical climatic year a value of 6 hours would be used.

- Snowmelt Factors—Melt Coef (Inches/Day-Deg-F)—.03. The P8 model predicts snowmelt runoff beginning and ending earlier than observed snowmelt. The lowest coefficient of the recommended range was selected to minimize the disparity between observed and predicted snowmelt (i.e., the coefficient minimizes the number of inches of snow melted per day and maximizes the number of snowmelt runoff days).

- Snowmelt Factors—Scale Factor For Max Abstraction—1. This factor controls the quantity of snowmelt runoff (i.e., controls losses due to infiltration). Selection was based upon the factor that resulted in the closest fit between modeled and observed runoff volumes.

- Growing Season AMC—II = .05 and AMC—III = 100. Selection of this factor was based upon the observation that the model accurately predicted runoff water volumes from monitored watersheds when the Antecedent Moisture Condition II was selected (i.e., curve numbers selected by the model are based upon antecedent moisture conditions). Modeled water volumes were less than observed volumes when Antecedent Moisture Condition I was selected and modeled water volumes exceeded observed volumes when Antecedent Moisture Condition III was selected. The selected parameters tell the model to only use Antecedent Moisture Condition I when less than 0.05 inches of rainfall occur during the five days prior to a rainfall event and to only use Antecedent Moisture Condition III if more than 100 inches of rainfall occur within five days prior to a rainfall event. Although the model does select AMC I and III for a small percentage of events (i.e., more events than seems appropriate), a good fit between modeled and observed water volumes was obtained.

Particle Scale Factor (Case-Edit-Components)

- Scale Fac.—TP—1.45. The particle scale factor determines the total phosphorus load generated by the particles predicted by the model in watershed runoff. The factor for total phosphorus was selected to match the observed annual total phosphorus load with modeled total phosphorus loads. Even with a particle scale factor of 1.45, the modeled loads for snowmelt runoff were significantly lower than observed loads. Therefore, the scale factor was selected to match the observed annual load without the snowmelt loading. We believe the discrepancy occurred because the model assumes open water and ideal treatment conditions during snowmelt. In reality, ponds are generally frozen when snowmelt begins and consequently higher loading occurs. It was determined that the snowmelt load predicted by the model must by multiplied by approximately 2 to accurately predict snowmelt phosphorus loading.

Particle File Selection (Case—Read—Particles)

- NURP50.PAR. The NURP 50 particle file was found to most accurately predict phosphorus loading to Round Lake.

Precipitation File Selection (Case—Edit—First—Prec. Data File)

- SNOED161.PCP. The precipitation file SNOED161.PCP is comprised of hourly precipitation measured at the Bryant Lake Precipitation Gage (i.e., located near T.H. 212 and I-494) during October 1 through November 24, 1996 and during March 13 through September 30, 1997. Precipitation data from the Minneapolis—St. Paul International Airport was used for the period November 25, 1996 through March 12, 1997. Three modifications were made to the file: (1) Precipitation during the January through March period was reduced from 1.81 inches to 1.61 inches (i.e., water equivalent). The reduction was made to match the modeled and observed snowmelt runoff volumes. (2) Precipitation during July 21, 1997 was reduced by 44 percent; and (3) precipitation during August 19, 1997 was reduced 27 percent. The changes were made to match observed and modeled runoff volumes on these dates.

Air Temperature File Selection (Case—Edit—First—Air Temp. File)

- msp4897.tmp. The temperature file was comprised of temperature data from the Minneapolis–St. Paul International airport during the period 1948 through 1997.

Devices Parameter Selection (Case—Edit—Devices—Data—Select Device)

- Detention Pond—Permanent Pool—Area and Volume—The surface area and dead storage volume of each detention pond was determined and entered here.

- Detention Pond—Flood Pool—Area and Volume—The surface area and storage volume under flood conditions (i.e., the storage volume between the normal level and flood elevation) was determined and entered here.

- Detention Pond—Infiltration Rate (in/hr)—0.005 for ponds partially located on marsh soils, 0.015 (dead storage pool) and 0.02 (flood storage pool) for ponds located on loam soils, and 0.05 for ponds located on sandy loam soils. The infiltration parameter selection was based upon pond level data (i.e., from a pond located on sandy loam soils) and from adjustments to match observed and modeled flows from other watershed ponds.

- Detention Pond—Orifice Diameter and Weir Length—The orifice diameter or weir length was determined for each detention pond and entered here.

- Detention Pond or Generalized Device—Particle Removal Scale Factor— 0.3 for ponds less than 2 feet deep and 1 for all ponds 3 feet deep or greater. The particle removal factor for watershed devices determines particle removal by devices. The factor was selected to match observed phosphorus loads and modeled loads. Insufficient information was available to say with certainty the particle removal scale factor for ponds 2 to 3 feet deep. A factor of 0.6 was used for all ponds of this depth. (Factors within the range of 0 to 1 were tried and a factor of 0.6 was selected. Because the ponds of this depth range were in the upstream portion of a series of ponds, and the observed data was downstream from them, the model was relatively insensitive to changes in this parameter.)

- Detention Pond or Generalized Device—Outflow Device Nos.—The number of the downstream device receiving water from the detention pond outflow was entered.

- Generalized Device—Infiltration Outflow Rates (cfs)—Although the infiltration rates listed under the detention pond category are the same, the outflow rates at each pond depth was calculated in cfs and entered.

- Pipe/Manhole—Time of Concentration—The time of concentration for each pipe/manhole device was determined and entered here. Also, a "dummy" pipe/manhole device was placed immediately upstream of each pond and a time of concentration of 0.5 hours per "dummy" pipe was selected to enable the model to accurately time the release of waters from each pond. Failure to use a "dummy" pipe/manhole for this purpose will result in a much faster release of waters from ponds and resultant reductions in treatment than actually occurs. Also, a "dummy" pipe/manhole was installed in the network to represent the lakes. This forced the model to total all loads (i.e., water, nutrients, etc.) entering the lake. Failure to enter the "dummy" pipe requires the modeler to manually tabulate the loads entering the lake.

Watersheds Parameter Selection (Case—Edit—Watersheds—Data—Select Watershed)

- Outflow Device Number—The Device Number of the Device receiving runoff from the watersheds was selected. The same number was selected for the Watersheds and Devices (e.g., Watershed RLE = 1 and Device RLE = 1).

- Pervious Curve Number—A weighted SCS Curve number was used as outlined in the following procedure. The Hennepin County Soils Survey was consulted to determine the soil types within each subwatershed and a pervious curve number was selected for each subwatershed based upon soil types, land use, and hydrologic conditions (e.g., if watershed soils are type C and pervious areas are comprised of grassed areas with >75% cover, then a Curve Number of 74 would be selected). The pervious curve number was then weighted with indirect (i.e., disconnected) impervious areas in each subwatershed as follows:

$$WCN = \frac{[(Indirect\ Impervious\ Area] * (98)] + [(Pervious\ Area) * (Pervious\ Curve\ Number)]}{Total\ Area}$$

The following assumptions for Direct Impervious and Total Impervious were used to determine the weighted curve numbers.

Land Use	Direct Impervious	Indirect Impervious	Total Impervious
Commerce	.80	.05	.85
Industrial/Office	.67	.05	.72
Institutional	.30	.10	.40
High Density Residential	.48	.17	.65
Medium Density Residential	.30	.08	.38
Low Density Residential	.25	.05	.30
Very Low Density Residential	.15	.05	.20
Natural/Paved/Open	0	.05	.05

- Swept/Not Swept—An "Unswept" assumption was made for the entire impervious watershed area. A Sweeping Frequency of 0 was selected. Selected parameters were placed in the "Swept" column since a sweeping frequency of 0 was selected.

- Impervious Fraction—The direct or connected impervious fraction for each subwatershed was estimated and entered here. The direct or connected impervious fraction includes driveways and parking areas that are directly connected to the storm sewer system. The previous table indicates was used to determine the direct impervious fractions for each land use type. Then, the average direct impervious fraction was determined by weighting the acres of each land use with the direct impervious fraction to obtain a weighted average.

- Depression Storage— .05

- Impervious Runoff Coef.— .92

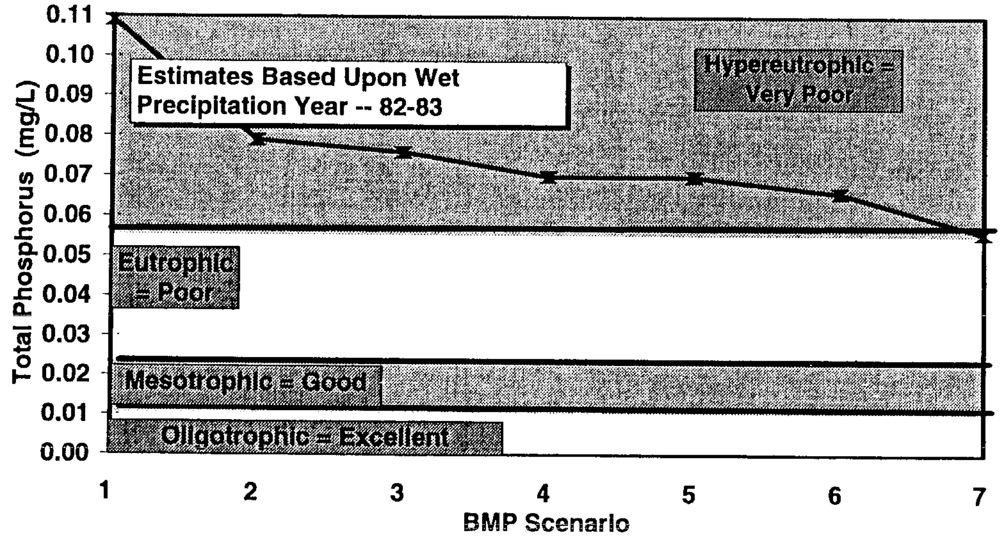
Passes Through the Storm File (Case—Edit—First—Passes Thru Storm File)

- Passes Thru Storm File—5. The number of passes through the storm file was determined after the model had been set up and a preliminary run completed. The selection of the number of passes through the storm file was based upon the number required to achieve model stability. Multiple passes through the storm file were required because the model assumes that dead storage waters contain no phosphorus. Consequently, the first pass through the storm file results in lower phosphorus loading than occurs with subsequent passes. Stability occurs when subsequent passes do not result in a change in phosphorus concentration in the pond waters. To determine the number of passes to select, the model was run with 3 passes, 5 passes, and 10 passes. A comparison of phosphorus predictions for all devices was evaluated to determine whether changes occurred between the three scenarios. If there is no difference between 3 and 5 passes, 3 passes are sufficient to achieve model stability. If differences are noted between 3 and 5 passes and no differences are noted between 5 and 10 passes, then 5 passes are sufficient to achieve model stability. Small differences were noted between 3 and 5 passes and no differences were noted between 5 and 10 passes. Therefore, it was determined that 5 passes through the storm file resulted in model stability for the Lake Lucy and Lake Ann project.

Appendix E

BMP Analysis: Water Quality Benefits of BMPs

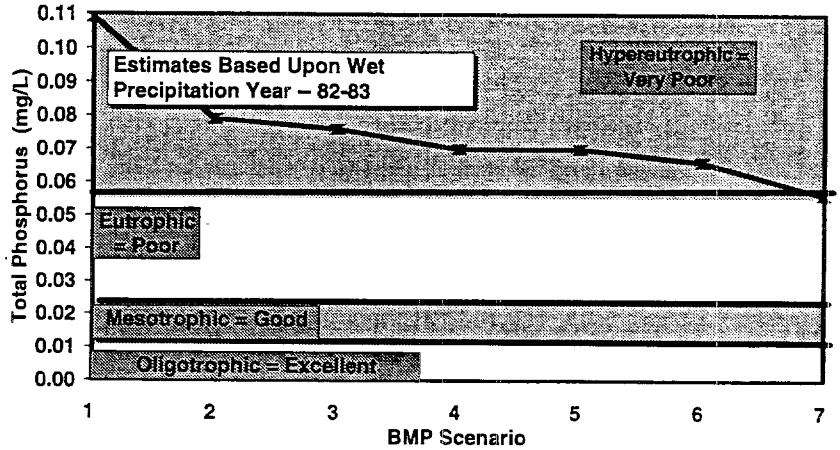
Lake Lucy: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



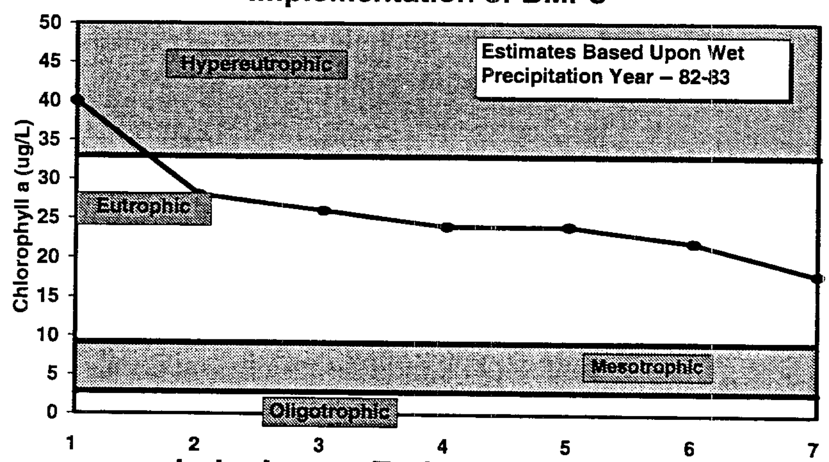
BMP Legend:

1 Preserve only DNR-Protected Wetlands
2 Preserve All Wetlands
3 "2" plus Upgrade Pond in LU-A3.4
4 "3" plus Add Pond in LU-A1.10
5 "4" plus Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.
6 "5" plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7 "6" plus Store Water in Infiltration Basins Througout the Lake Lucy and Lake Ann Watersheds

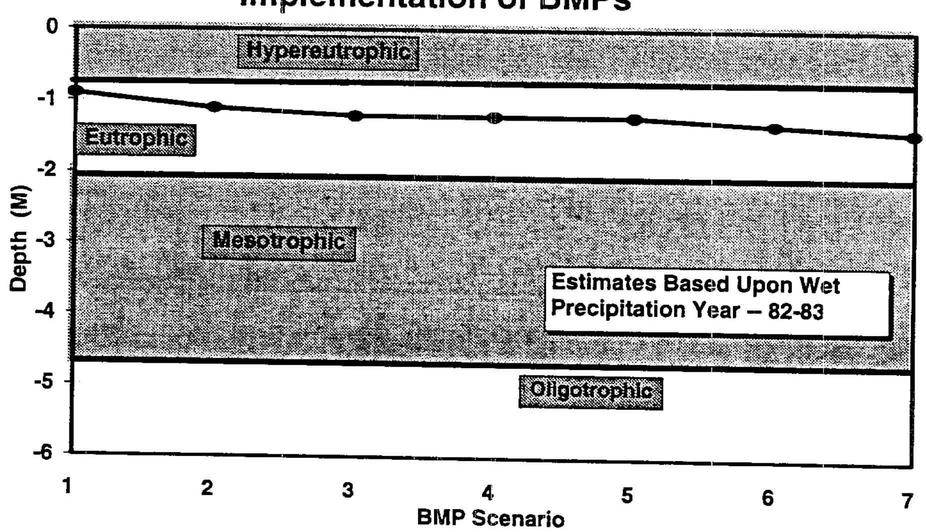
Lake Lucy: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



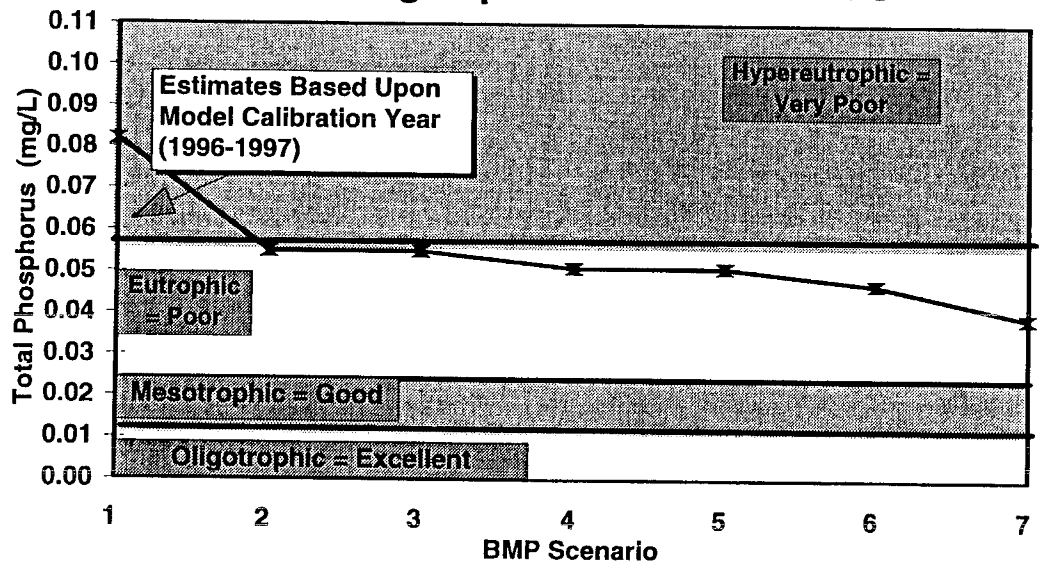
Lake Lucy: Estimated Avg. Summer Chlorophyll Concentration Following Implementation of BMPs



Lake Lucy: Estimated Avg. Summer Secchi Disc Transparency Following Implementation of BMPs



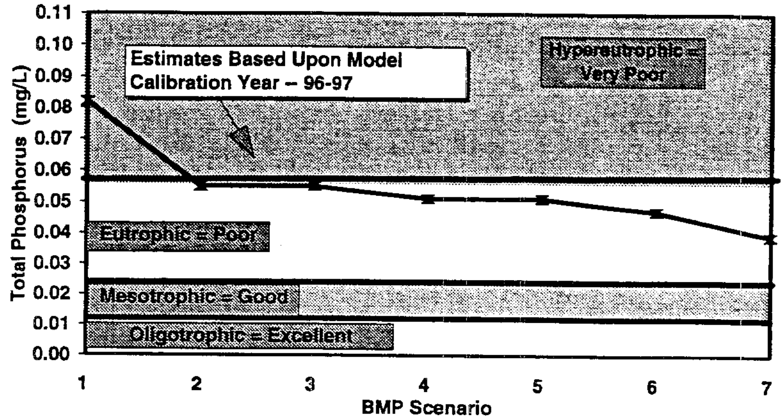
Lake Lucy: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



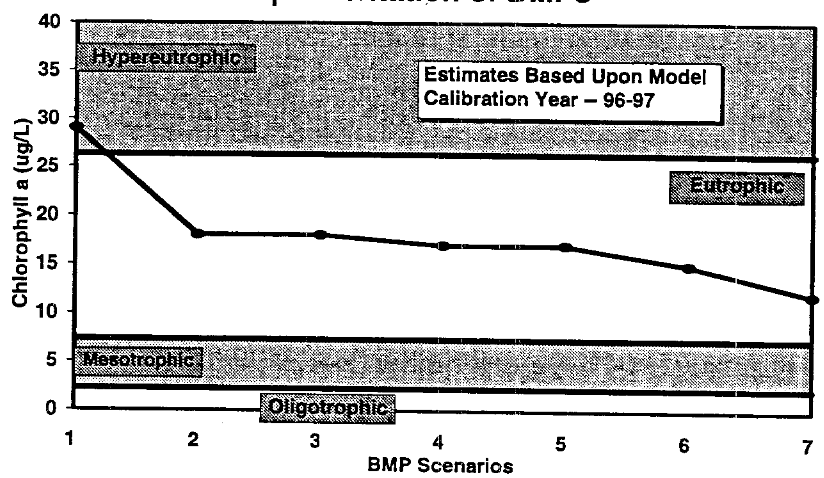
BMP Legend:

1 Preserve only DNR-Protected Wetlands
2 Preserve All Wetlands
3 "2" plus Upgrade Pond in LU-A3.4
4 "3" plus Add Pond in LU-A1.10
5 "4" plus Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9
6 "5" plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14,
7 "6" plus Store Water in Infiltration Basins Througout the Lake Lucy and Lake Ann Watersheds

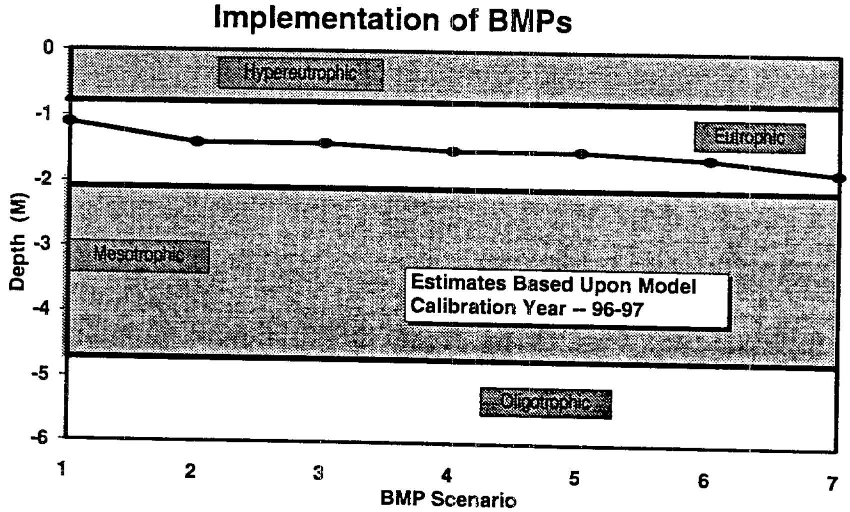
Lake Lucy: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



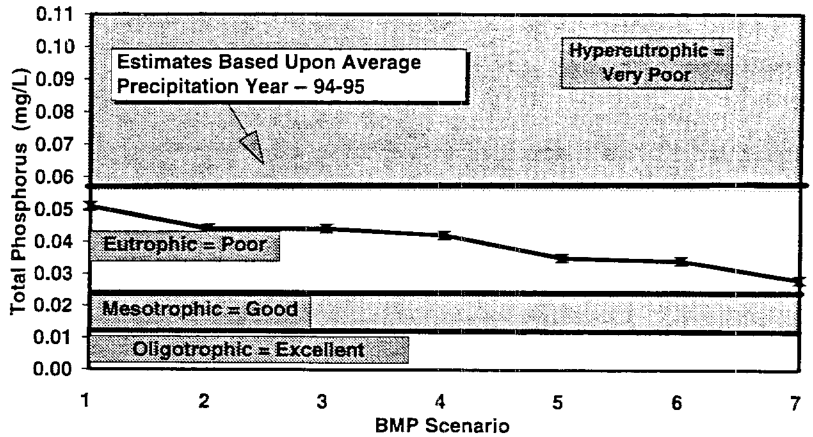
Lake Lucy: Estimated Avg. Summer Chlorophyll Concentration Following Implementation of BMPs



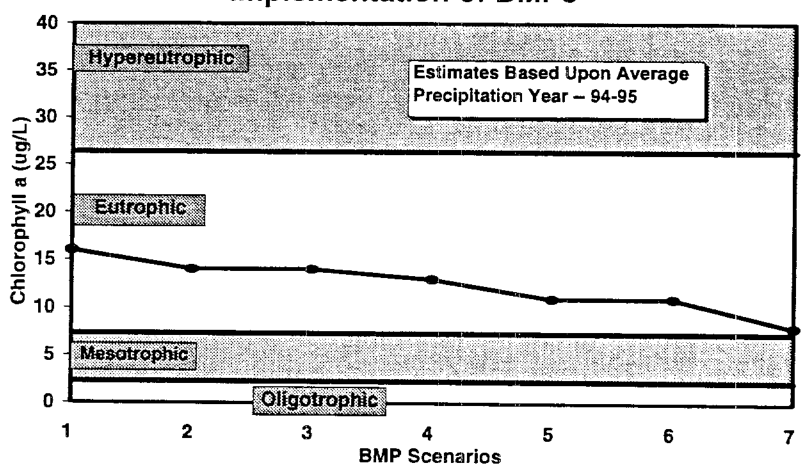
Lake Lucy: Estimated Avg. Summer Secchi Disc Transparency Following Implementation of BMPs



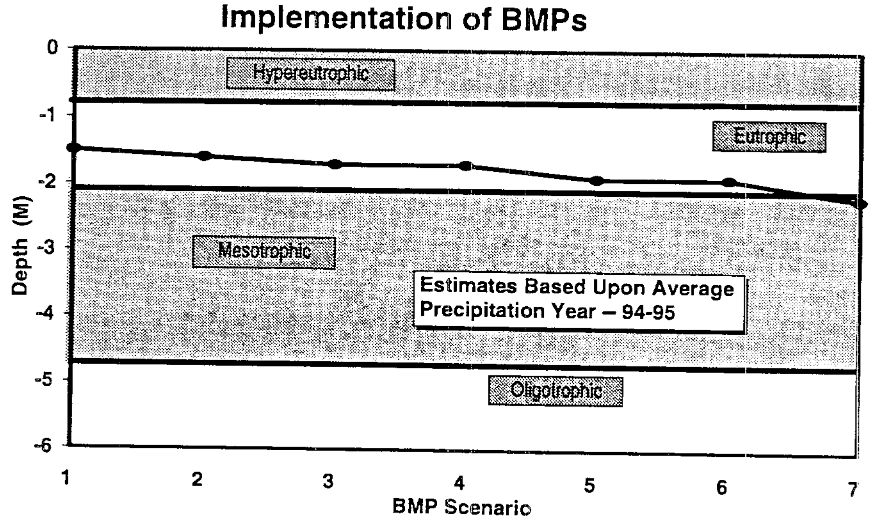
Lake: Ann Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



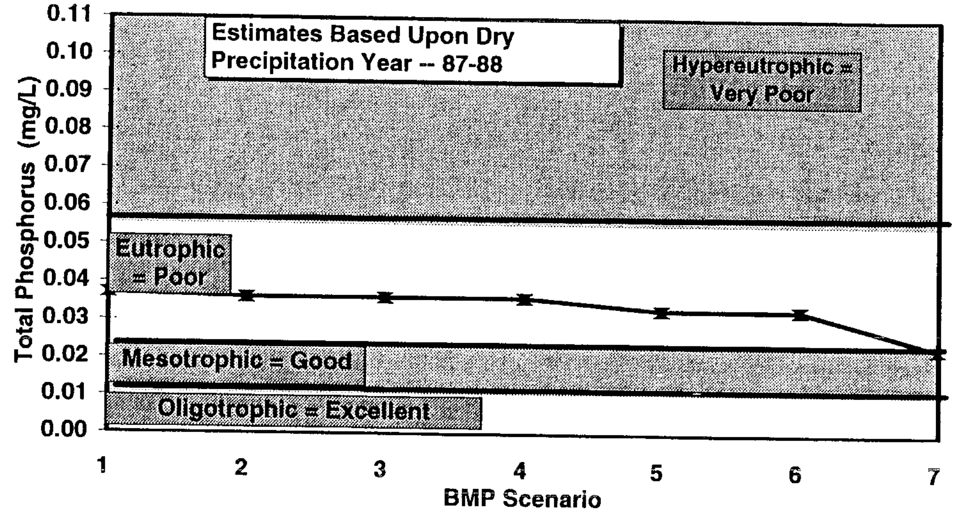
Lake Ann: Estimated Avg. Summer Chlorophyll Concentration Following Implementation of BMPs



Lake Ann: Estimated Avg. Summer Secchi Disc Transparency Following Implementation of BMPs



Lake Ann: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs

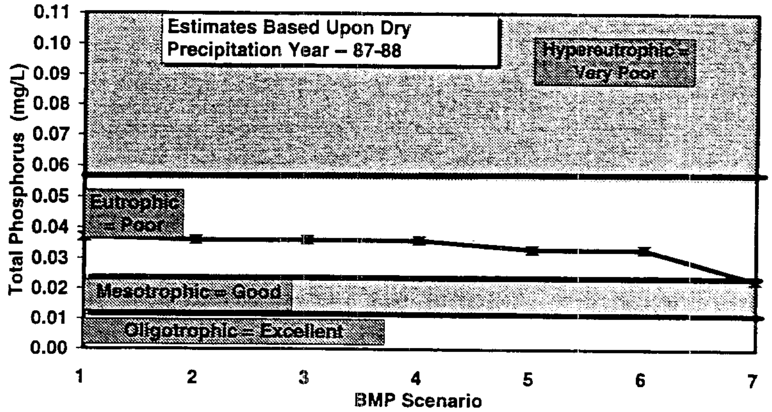


BMP Legend:

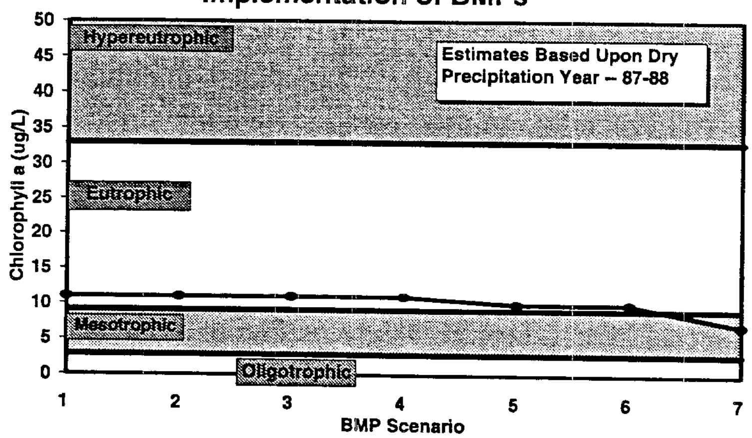
1 Preserve only DNR-Protected Wetlands
2 Preserve All Wetlands
3 "2" plus Upgrade Pond in LU-A3.4
4 "3" plus Add Pond in LU-A1.10
5 "4" plus Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.
6 "5" plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14,
7 "6" plus Store Water in Infiltration Basins Througout the Lake Lucy and Lake Ann Watersheds

Note: The summer average TP concentration for the dry year may be slighly overestimated as it is calculated as Cannfield and Bachmann's annual average TP concentration.

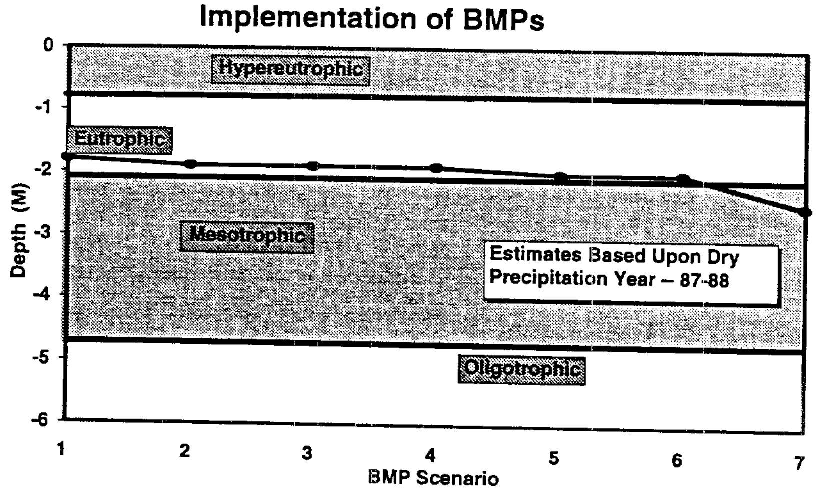
Lake Ann: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



Lake Ann: Estimated Avg. Summer Chlorophyll a Concentration Following Implementation of BMPs

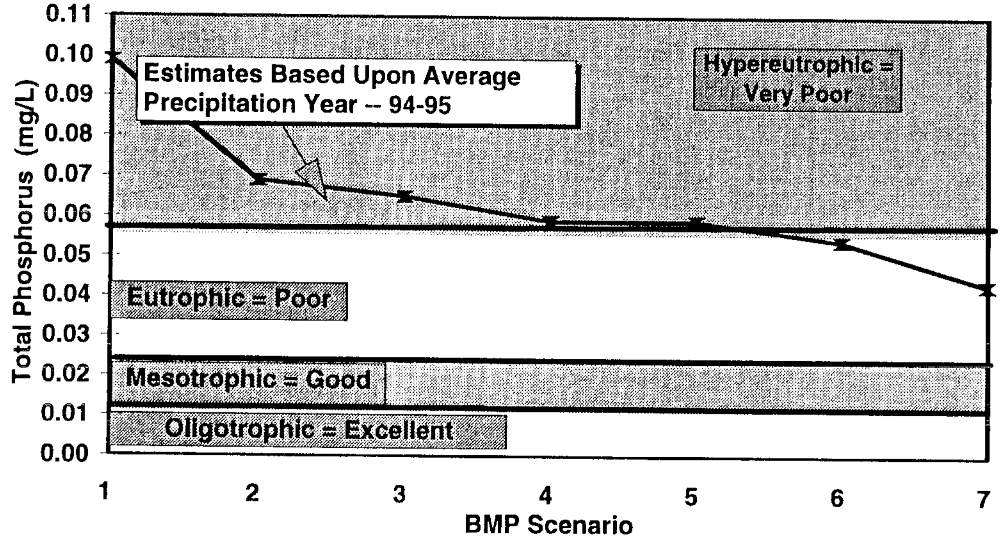


Lake Ann: Estimated Avg. Summer Secchi Disc Transparency Following Implementation of BMPs



Note: The summer average values for the dry year may be slighly overestimated because TP is calculated as Cannfield and Bachmann's annual average TP concentration.

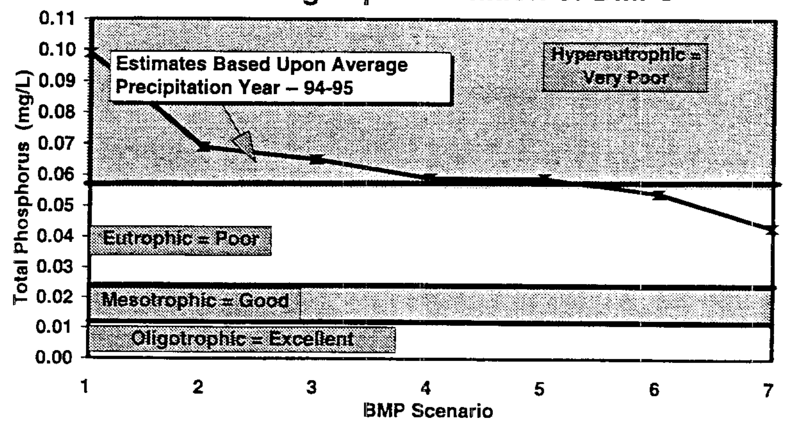
Lake: Lucy Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



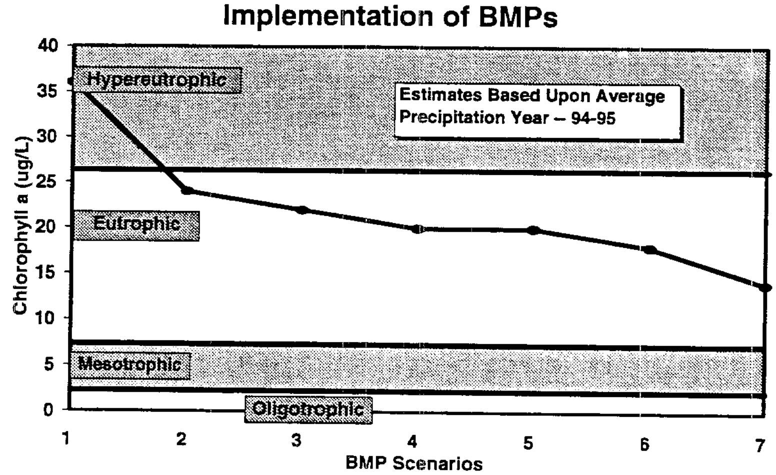
BMP Legend:

1 Preserve only DNR-Protected Wetlands
2 Preserve All Wetlands
3 "2" plus Upgrade Pond in LU-A3.4
4 "3" plus Add Pond in LU-A1.10
5 "4" plus Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.
6 "5" plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7 "6" plus Store Water in Infiltration Basins Througout the Lake Lucy and Lake Ann Watersheds

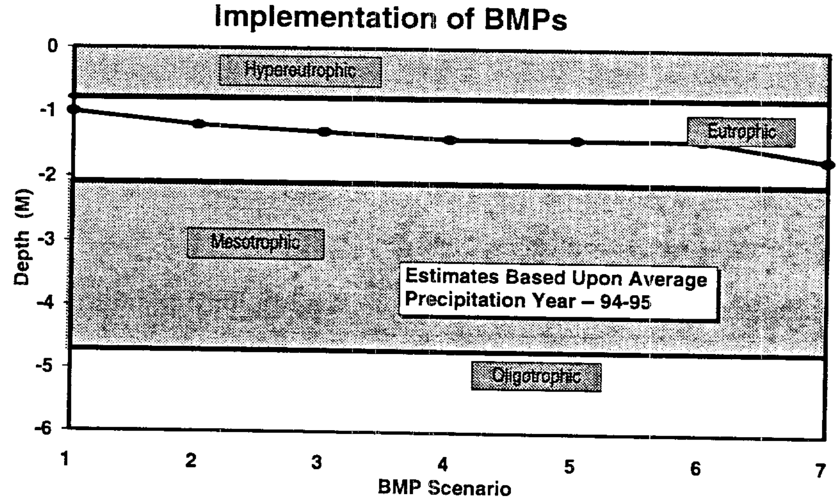
Lake: Lucy Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



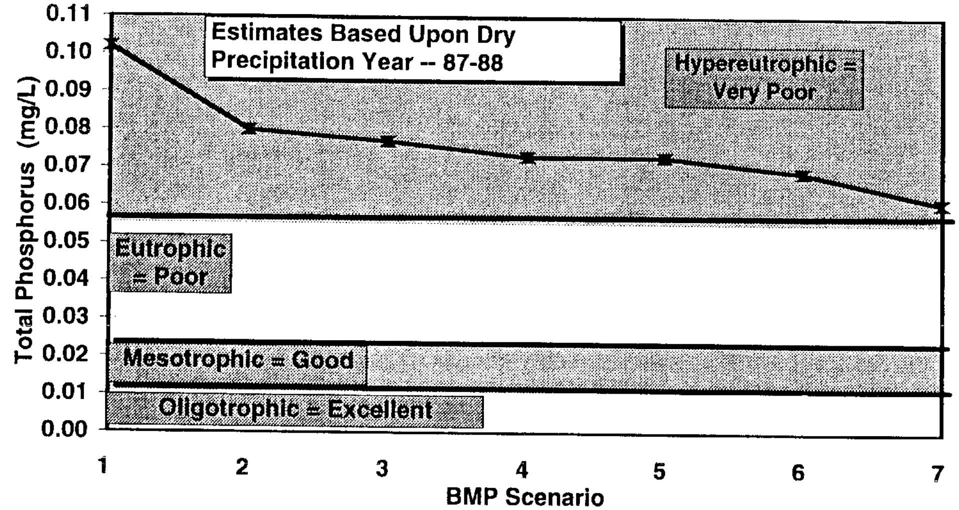
Lake Lucy: Estimated Avg. Summer Chlorophyll Concentration Following Implementation of BMPs



Lake Lucy Estimated Avg. Summer Secchi Disc Transparency Following Implementation of BMPs



Lake Lucy: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs

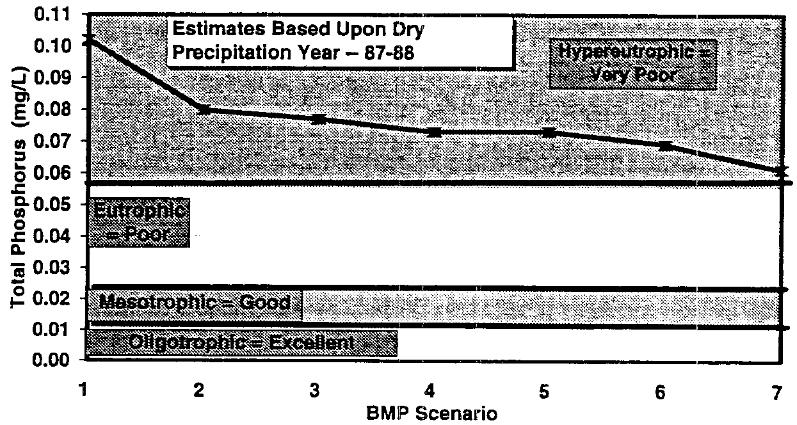


BMP Legend:

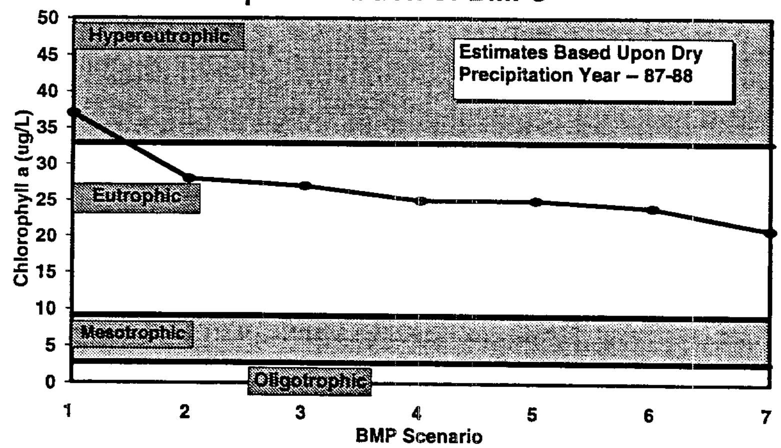
1 Preserve only DNR-Protected Wetlands
2 Preserve All Wetlands
3 "2" plus Upgrade Pond in LU-A3.4
4 "3" plus Add Pond in LU-A1.10
5 "4" plus Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.9
6 "5" plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14,
7 "6" plus Store Water in Infiltration Basins Througout the Lake Lucy and Lake Ann Watersheds

Note: The summer average TP concentration for the dry year may be slighly overestimated as it is calculated as Cannfield and Bachmann's annual average TP concentration.

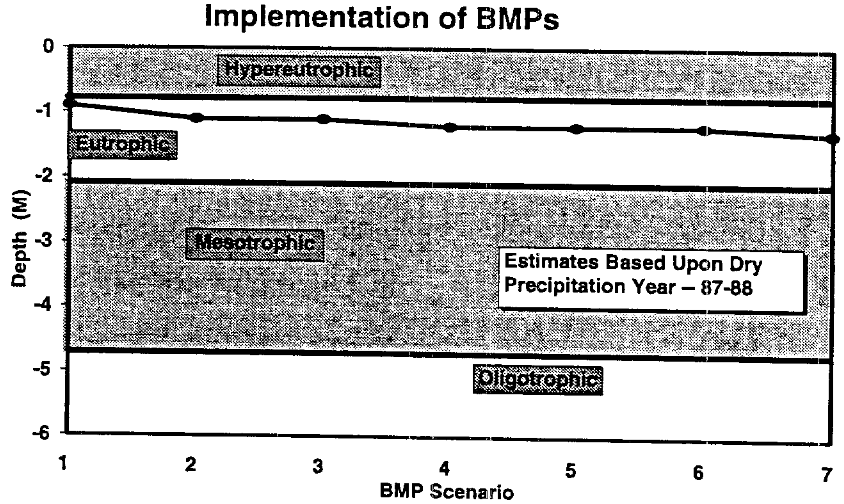
Lake Lucy: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



Lake Lucy: Estimated Avg. Summer Chlorophyll a Concentration Following Implementation of BMPs

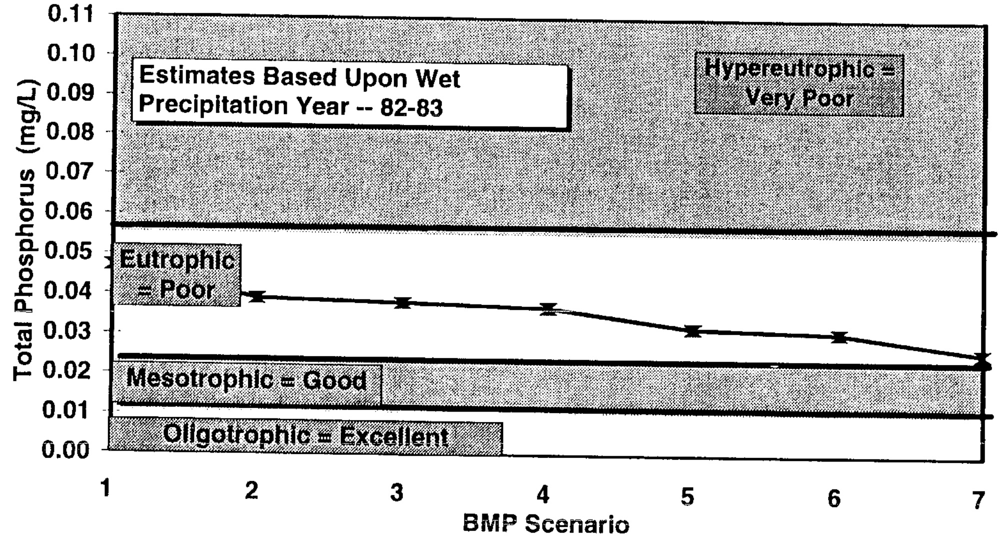


Lake Lucy: Estimated Avg. Summer Secchi Disc Transparency Following Implementation of BMPs



Note: The summer average values for the dry year may be slighly overestimatec because TP is calculated as Cannfield and Bachmann's annual average TP concentration.

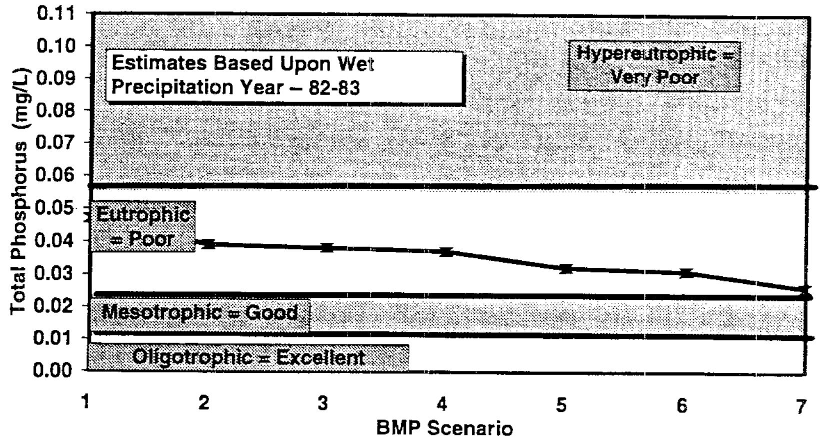
Lake Ann: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



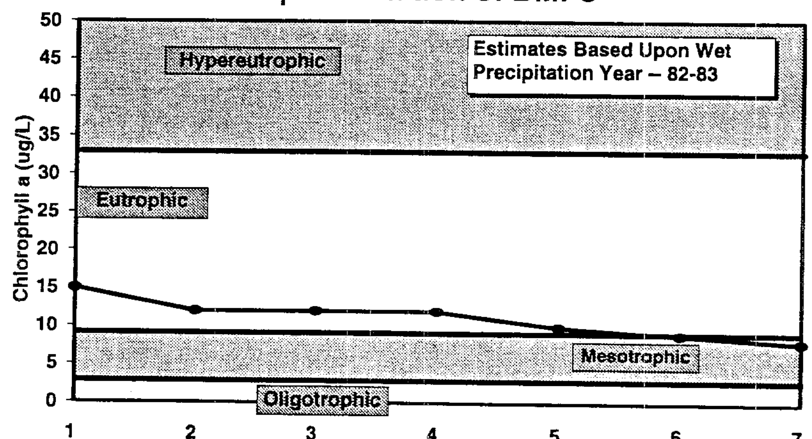
BMP Legend:

1 Preserve only DNR-Protected Wetlands
2 Preserve All Wetlands
3 "2" plus Upgrade Pond in LU-A3.4
4 "3" plus Add Pond in LU-A1.10
5 "4" plus Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.
6 "5" plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7 "6" plus Store Water in Infiltration Basins Througout the Lake Lucy and Lake Ann Watersheds

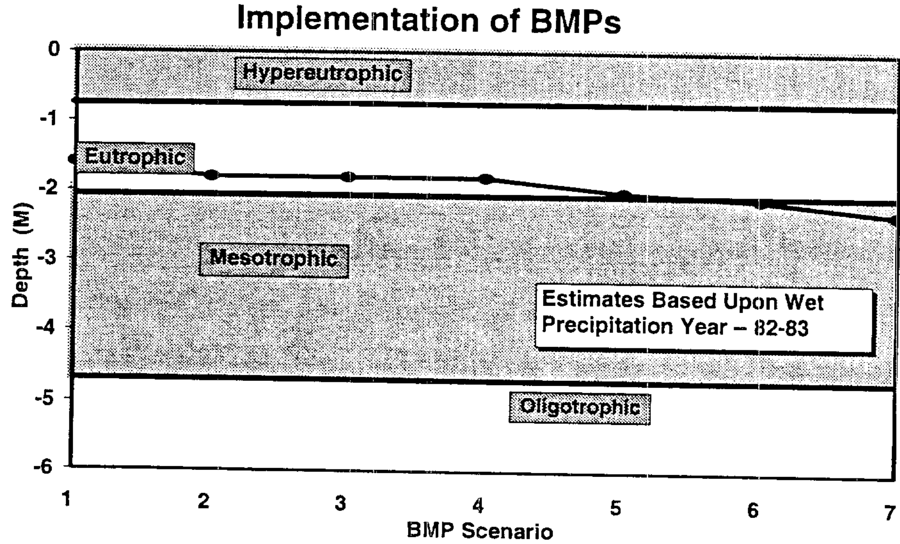
Lake Ann: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



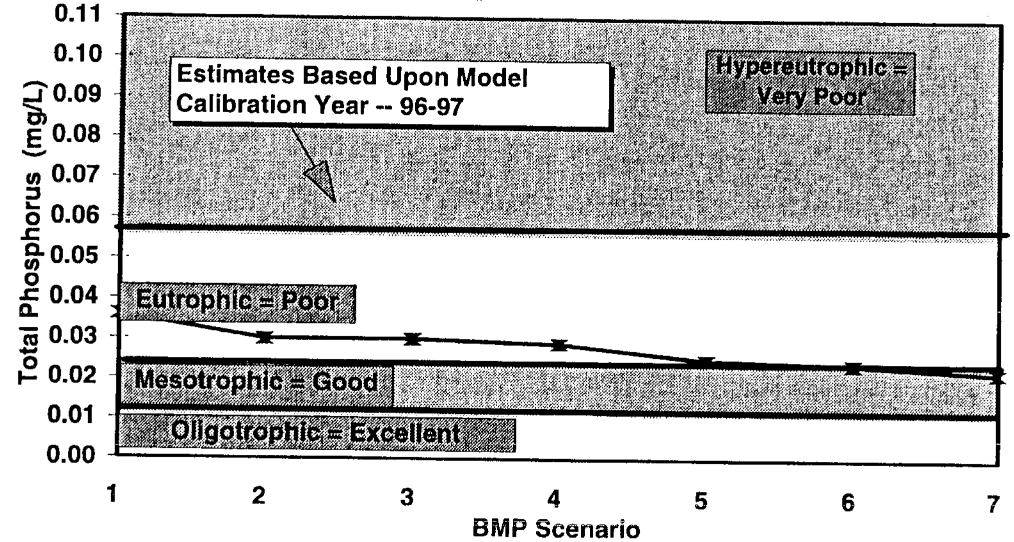
Lake Ann: Estimated Avg. Summer Chlorophyll Concentration Following Implementation of BMPs



Lake Ann: Estimated Avg. Summer Secchi Disc Transparency Following Implementation of BMPs



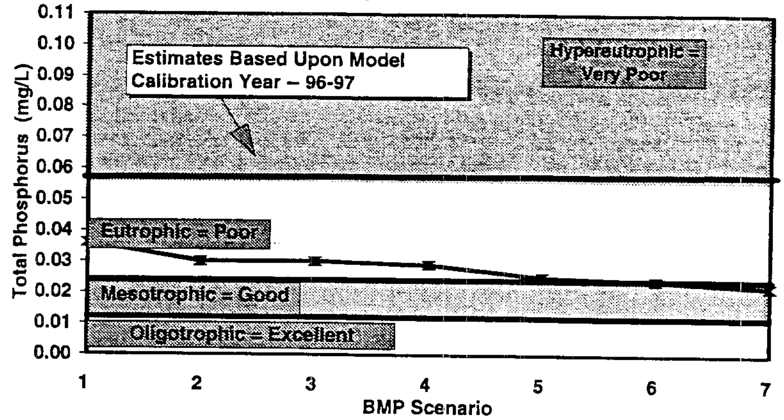
Lake Ann: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



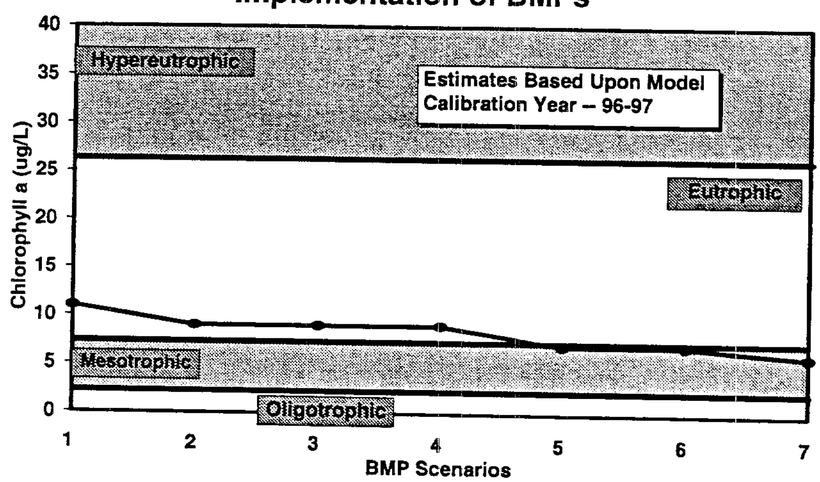
BMP Legend:

1 Preserve only DNR-Protected Wetlands
2 Preserve All Wetlands
3 "2" plus Upgrade Pond in LU-A3.4
4 "3" plus Add Pond in LU-A1.10
5 "4" plus Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.
6 "5" plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7 "6" plus Store Water in Infiltration Basins Througout the Lake Lucy and Lake Ann Watersheds

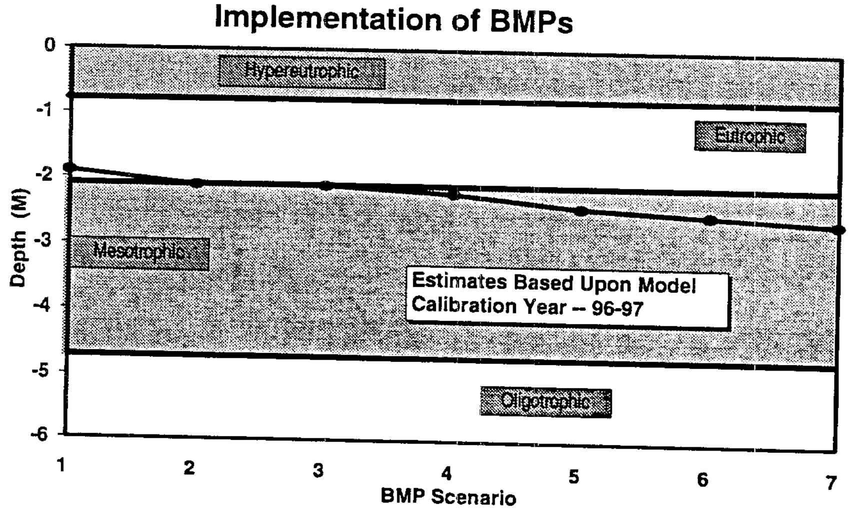
Lake Ann: Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



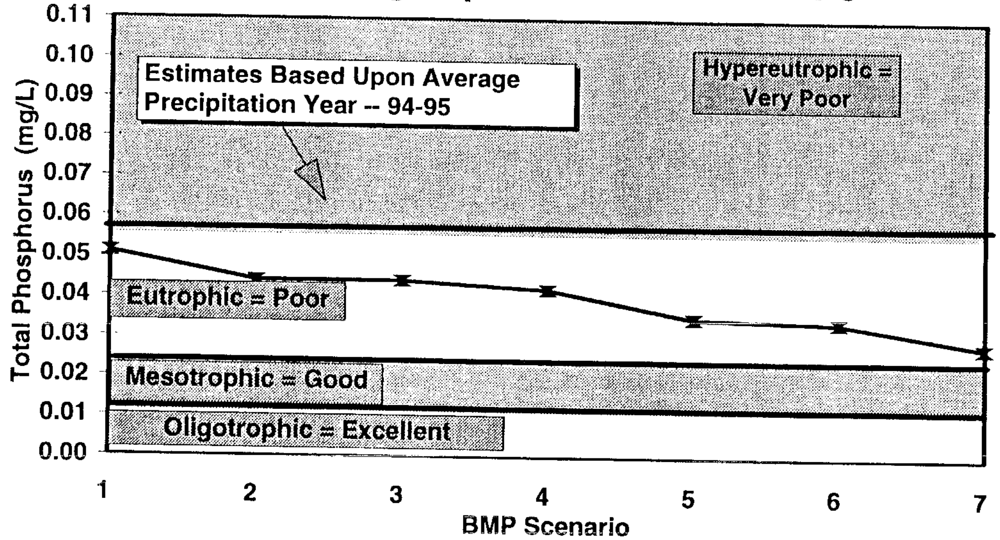
Lake Ann: Estimated Avg. Summer Chlorophyll Concentration Following Implementation of BMPs



Lake Ann: Estimated Avg. Summer Secchi Disc Transparency Following Implementation of BMPs



Lake: Ann Estimated Avg. Summer Total Phosphorus Concentration Following Implementation of BMPs



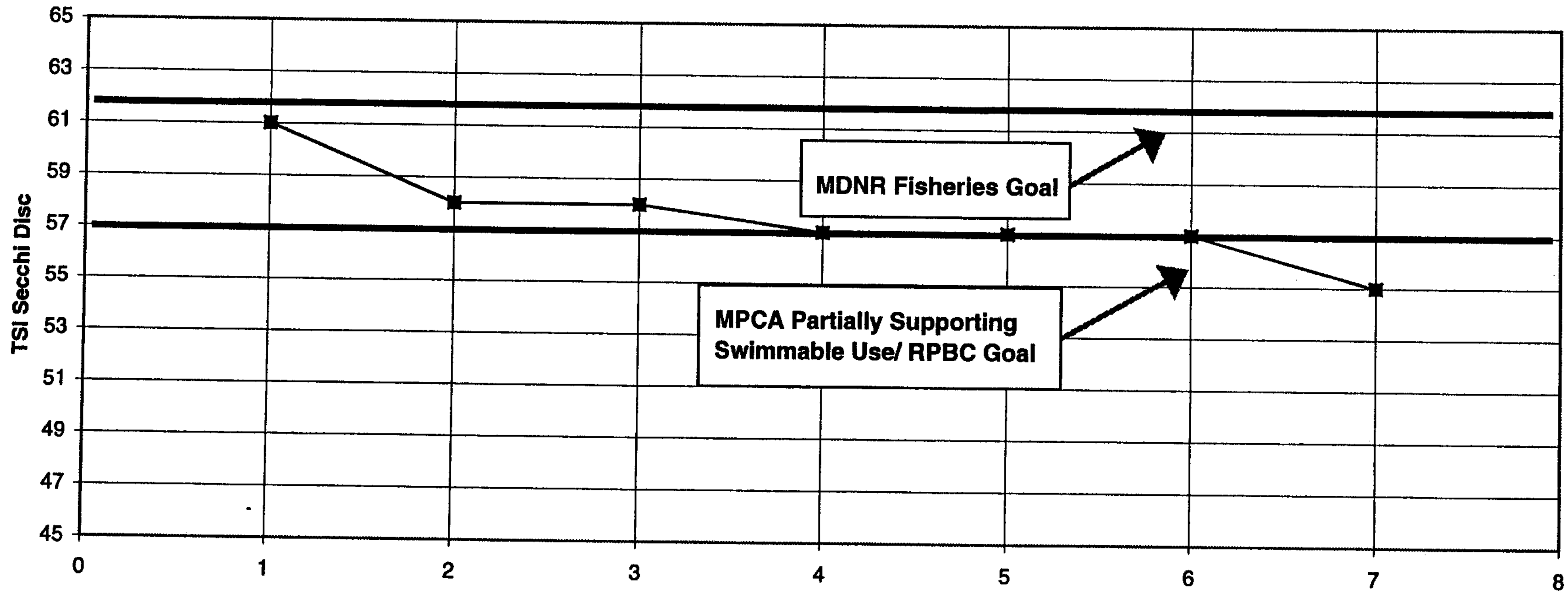
BMP Legend:

1 Preserve only DNR-Protected Wetlands
2 Preserve All Wetlands
3 "2" plus Upgrade Pond in LU-A3.4
4 "3" plus Add Pond in LU-A1.10
5 "4" plus Add Ponds in LA-A1.2, LA-A1.3, LA-A1.5, LA-A1.7, LA-A1.
6 "5" plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4, LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7 "6" plus Store Water in Infiltration Basins Througout the Lake Lucy and Lake Ann Watersheds

Appendix F

BMP Analysis: Goal Achievement of BMPs

Lake Lucy: Estimated TSI Secchi Disc Following Implementation of BMPs
WET YEAR



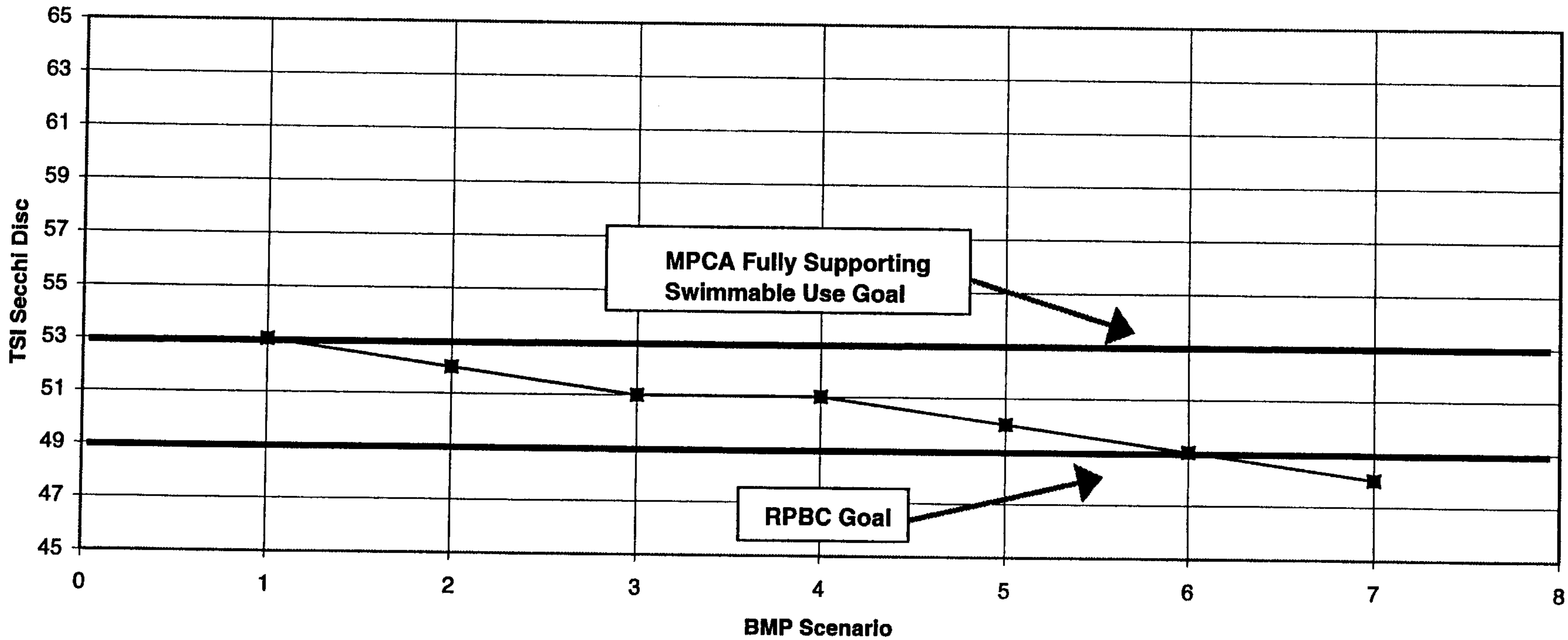
BMP Legend

1: Do Nothing (Preserve only DNR-Protected Wetlands)
2: Preserve all Wetlands
3: "2" Plus Upgrade Wetland in LU-A3.4
4: "3" Plus Add Pond in LU-A1.10
5: "4" Plus Add Ponds in LA-1.2, LA-1.3, LA-1.5, LA-1.7, LA-1.9
6: "5" Plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4 LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7: "6" Plus Store Water in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds

Note: There is no improvement shown in BMP Scenario 5 because these ponds are in the Lake Ann watershed.

P:\23\27\053\ela\TSI_Summary2.xls

Lake Ann: Estimated TSI Secchi Disc Following Implementation of BMPs *WET YEAR*

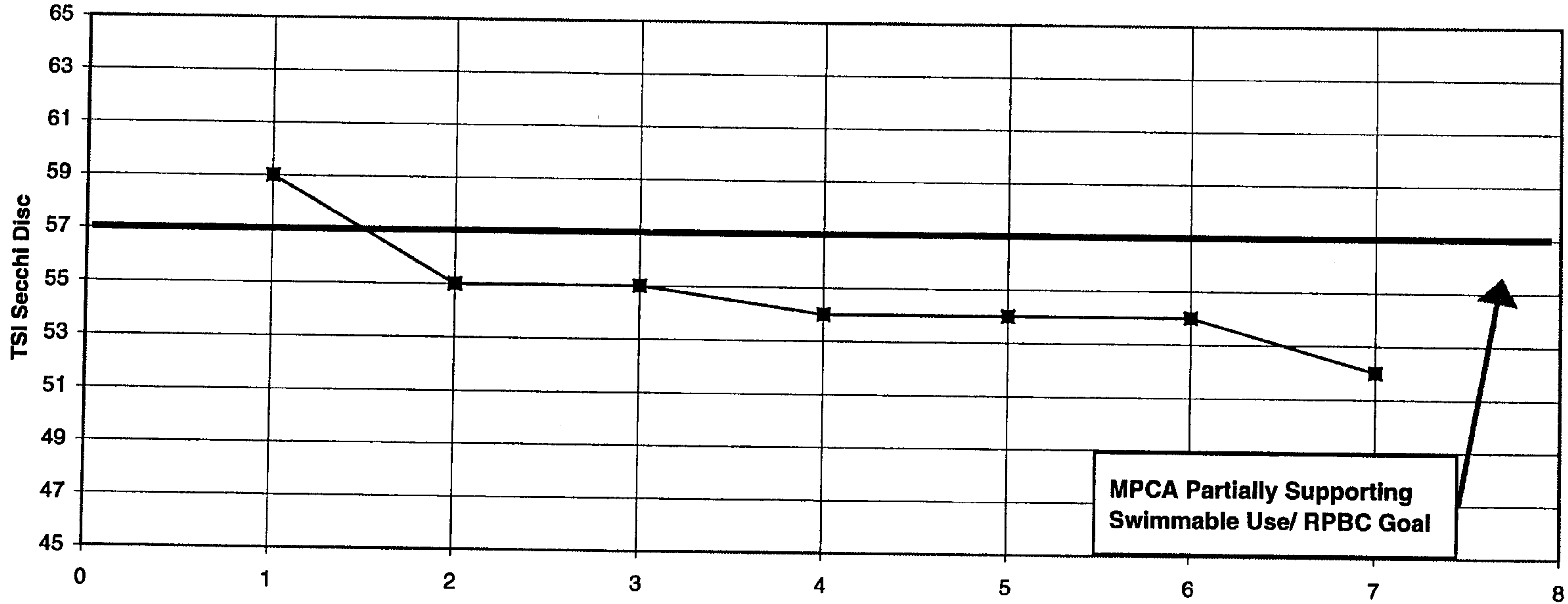


BMP Legend

- 1: Do Nothing (Preserve only DNR-Protected Wetlands)
- 2: Preserve all Wetlands
- 3: "2" Plus Upgrade Wetland in LU-A3.4
- 4: "3" Plus Add Pond in LU-A1.10
- 5: "4" Plus Add Ponds in LA-1.2, LA-1.3, LA-1.5, LA-1.7, LA-1.9
- 6: "5" Plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4 LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
- 7: "6" Plus Store Water in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds

P:\23\27\053\ela\TSI_Summary2.xls

Lake Lucy: Estimated TSI Secchi Disc
Following Implementation of BMPs
CALIBRATION YEAR

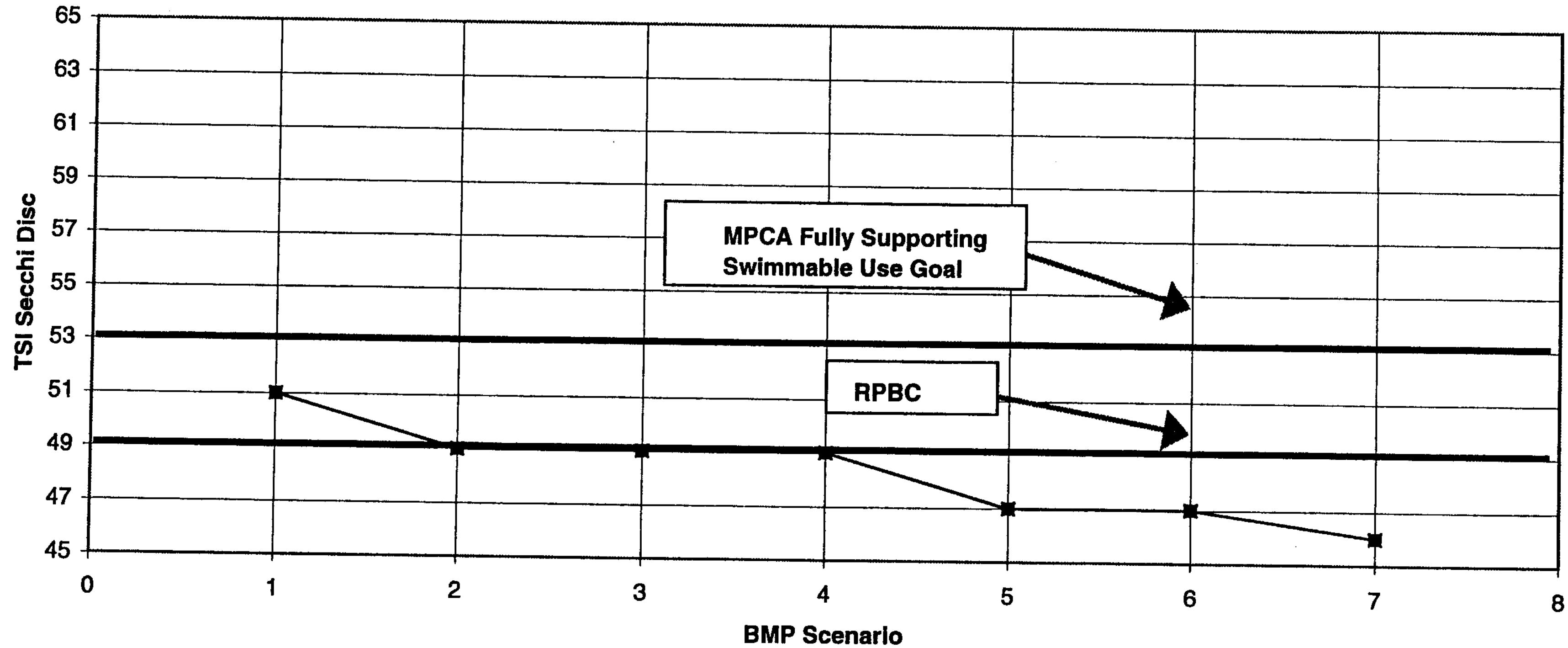


BMP Legend

1: Do Nothing (Preserve only DNR-Protected Wetlands)
2: Preserve all Wetlands
3: "2" Plus Upgrade Wetland in LU-A3.4
4: "3" Plus Add Pond in LU-A1.10
5: "4" Plus Add Ponds in LA-1.2, LA-1.3, LA-1.5, LA-1.7, LA-1.9
6: "5" Plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4 LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7: "6" Plus Store Water in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds

Note: There is no improvement shown in BMP Scenario 5 because these ponds are in the Lake Ann watershed.

Lake Ann: Estimated TSI Secchi Disc Following Implementation of BMPs CALIBRATION YEAR



BMP Legend

1: Do Nothing (Preserve only DNR-Protected Wetlands)
2: Preserve all Wetlands
3: "2" Plus Upgrade Wetland in LU-A3.4
4: "3" Plus Add Pond in LU-A1.10
5: "4" Plus Add Ponds in LA-1.2, LA-1.3, LA-1.5, LA-1.7, LA-1.9
6: "5" Plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4 LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7: "6" Plus Store Water in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds

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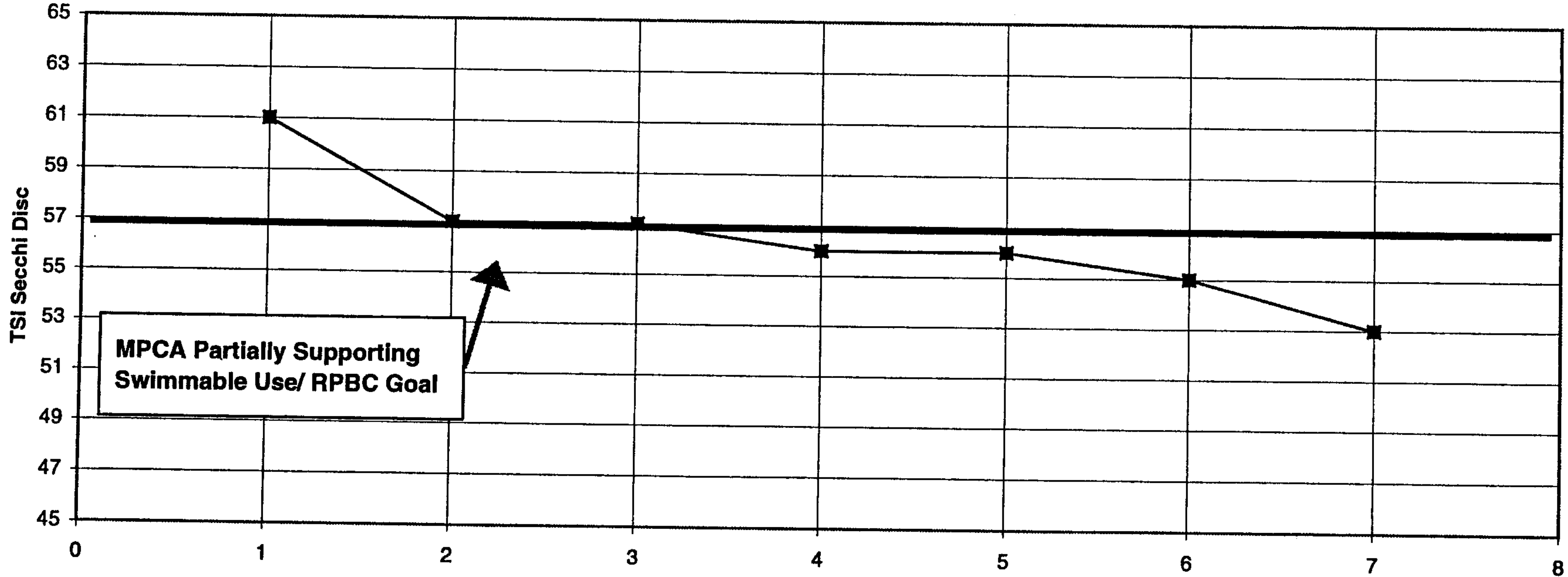
Lake Lucy: Estimated TSI Secchi Disc Following Implementation of BMPs *AVERAGE YEAR*



BMP Legend

1: Do Nothing (Preserve only DNR-Protected Wetlands)
2: Preserve all Wetlands
3: "2" Plus Upgrade Wetland in LU-A3.4
4: "3" Plus Add Pond in LU-A1.10
5: "4" Plus Add Ponds in LA-1.2, LA-1.3, LA-1.5, LA-1.7, LA-1.9
6: "5" Plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4 LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7: "6" Plus Store Water in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds

Note: There is no improvement shown in BMP Scenario 5 because these ponds are in the Lake Ann watershed.

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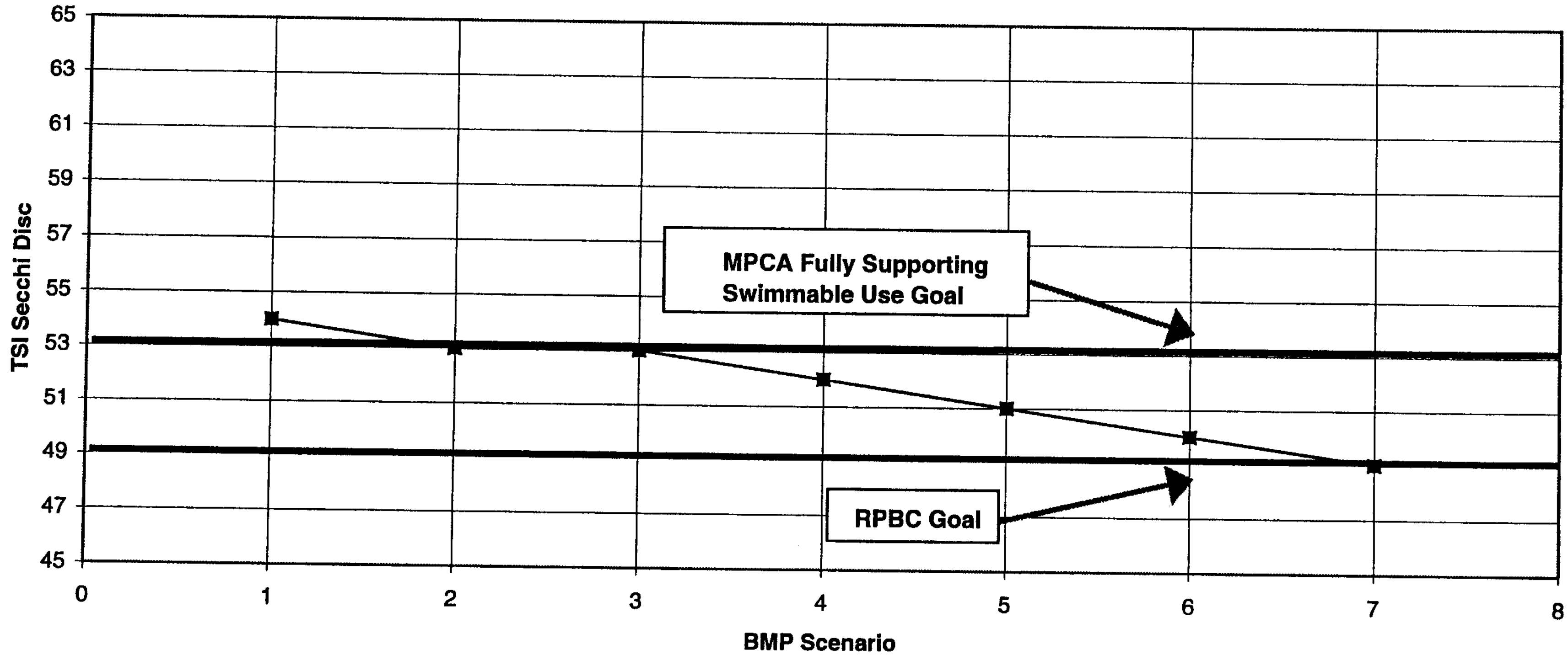
Lake Ann: Estimated TSI Secchi Disc Following Implementation of BMPs
AVERAGE YEAR



BMP Legend

1: Do Nothing (Preserve only DNR-Protected Wetlands)
2: Preserve all Wetlands
3: "2" Plus Upgrade Wetland in LU-A3.4
4: "3" Plus Add Pond in LU-A1.10
5: "4" Plus Add Ponds in LA-1.2, LA-1.3, LA-1.5, LA-1.7, LA-1.9
6: "5" Plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4 LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7: "6" Plus Store Water in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds

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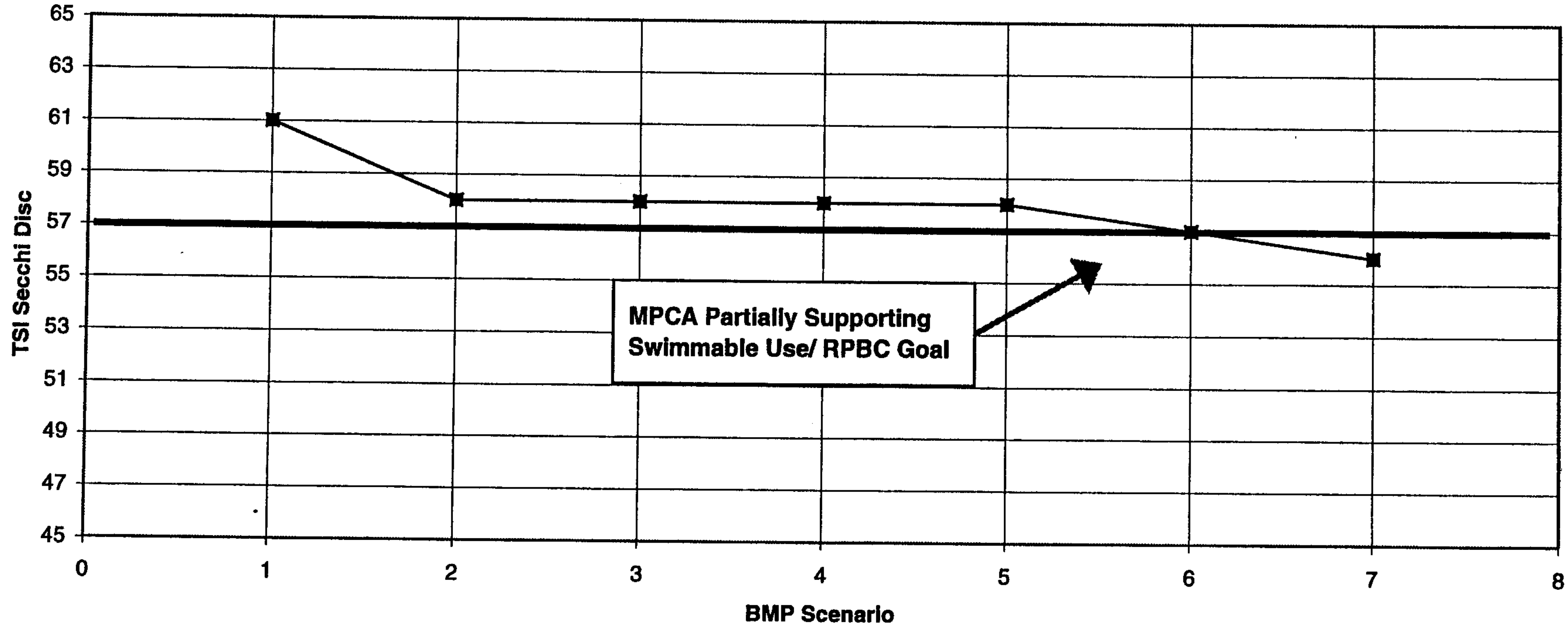
Lake Lucy: Estimated TSI Secchi Disc Following Implementation of BMPs
DRY YEAR



BMP Legend

1: Do Nothing (Preserve only DNR-Protected Wetlands)
2: Preserve all Wetlands
3: "2" Plus Upgrade Wetland in LU-A3.4
4: "3" Plus Add Pond in LU-A1.10
5: "4" Plus Add Ponds in LA-1.2, LA-1.3, LA-1.5, LA-1.7, LA-1.9
6: "5" Plus Upgrade Pond in LU-A5.2 and Add Ponds in LU-A5.4 LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7: "6" Plus Store Water in Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds

Note: There is no improvement shown in BMP Scenario 5 because these ponds are in the Lake Ann watershed.

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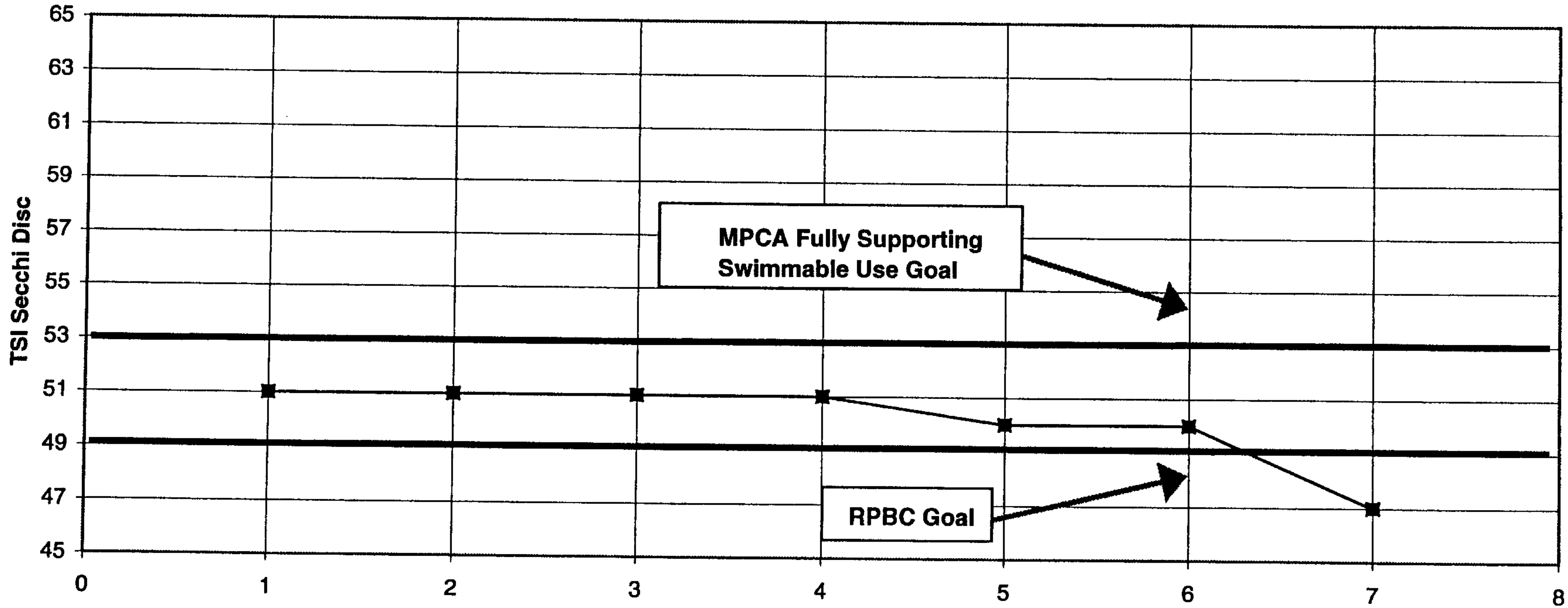
Lake Ann: Estimated TSI Secchi Disc Following Implementation of BMPs
DRY YEAR



BMP Legend

1: Do Nothing (Preserve only DNR-Protected Wetlands)
2: Preserve all Wetlands
3: "2" Plus Upgrade Wetland In LU-A3.4
4: "3" Plus Add Pond In LU-A1.10
5: "4" Plus Add Ponds In LA-1.2, LA-1.3, LA-1.5, LA-1.7, LA-1.9
6: "5" Plus Upgrade Pond In LU-A5.2 and Add Ponds In LU-A5.4 LU-A5.10, LU-A5.11, LU-A5.12, LU-A5.13, LU-A5.14
7: "6" Plus Store Water In Infiltration Basins Throughout the Lake Lucy and Lake Ann Watersheds

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